Ecosystem Considerations for 1998

Compiled and Reviewed by
The Plan Teams for the Groundfish Fisheries
of the Bering Sea, Aleutian Islands, and Gulf of Alaska

With Contributions by
C. Blackburn, J. DiCosimo, T. Faris, R. Ferrero, L. Fritz, J. Fujioka,
J. Heifetz, V. Mendenhall, R. Merrick, J. Sease, I. Vining, and D. Witherell

North Pacific Fishery Management Council
605 West 4th Avenue, Suite 306
Anchorage, Alaska 99501-2252

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INTRODUCTION

Since 1995, the North Pacific Fishery Management Councils (NPFMC) Groundfish Plan Teams have prepared a separate Ecosystem Considerations section to the annual SAFE report. The intent of the Ecosystems Considerations section is to provide the Council with information about the effects of fishing from a ecosystems perspective. The effects of fishing on ecosystems have not been incorporated into most single species stock assessments, in part due to data limitations. This information is useful for effective fishery management and maintaining sustainability of marine ecosystems. The Ecosystems Considerations chapter attempts to bridge this gap by identifying specific ecosystem concerns that should be considered by fishery managers, particularly during the annual process of setting catch limits on groundfish.

Each new Ecosystem Considerations report provides updates and new information to supplement the original report. The original 1995 report presented a compendium of general information on the Bering Sea, Aleutian Island, and Gulf of Alaska ecosystems as well as a general discussion of ecosystem management. The 1996 Ecosystems Considerations report provided additional information on biological features of the North Pacific, and highlighted the effects of bycatch and discards on the ecosystem. The 1997 Ecosystems Considerations report provided a review of ecosystem-based management literature and ongoing ecosystem research, and provided supplemental information on seabirds and marine mammals. This year's edition provides information on the precautionary approach, essential fish habitat, an overview of the effects of fishing gear on habitat, el Nino, collection of local knowledge, and other ecosystem information.

ECOSYSTEM CONSIDERATIONS

by Dave Witherell

What's New in Ecosystem-Based Management?

In 1996, the Council established an Ecosystem Committee to discuss possible approaches to incorporating ecosystem concerns into the fishery management process. The Committee has been quite active. In 1997, the committee held a 2 day workshop on ecosystem research, held several meetings to discuss essential fish habitat, and has hosted numerous informal discussions on ecosystem-based management and habitat concerns. A full-day meeting of the committee has been scheduled for December 7 to review the status of groundfish stocks and make recommendations to the Council on catch limits.

The Committee has worked to develop a working definition of ecosystem-based management to serve a a guide for future Council policy. The primary principles and elements of ecosystem-based management identified by the committee were published in five papers (Grumbine 1994, USFWS 1994, Mangle et al. 1995, Christiansen et al. 1996, Larkin 1996). The concept of ecosystem-based management includes the elements of sustainability, goals, ecological models and understanding, complexity, dynamic character, context and scale, adaptability, and humans as ecosystem components. The working definition, as revised, is shown in the adjacent box; additional changes may be made in the future.

Working Definition for Ecosystem-Based Management in the Context of the NPFMC

Definition: Ecosystem-based management, as defined by the NPFMC, is a strategy to regulate human activity towards maintaining long-term system sustainability (within the range of natural variability as we understand it) of the North Pacific, covering the Gulf of Alaska, the Eastern and Western Bering Sea, and the Aleutian Islands region.

Objective: Provide future generations the opportunities and resources we enjoy today.

Principles:
1. Maintain biodiversity consistent with natural evolutionary and ecological processes, including dynamic change and variability.
2. Maintain and restore habitats essential for fish and their prey.
3. Maintain system sustainability and sustainable yields of resources for human consumption and non-extractive uses.
4. Maintain the concept that humans are components of the ecosystem.

Guidelines:
1. Integrate ecosystem-based management through interactive partnerships with other agencies, stakeholders, and public.
2. Utilize sound ecological models as an aid in understanding the structure, function, and dynamics of the ecosystem.
3. Utilize research and monitoring to test ecosystem approaches.
4. Use precaution when faced with uncertainties to minimize risk; management decisions should err on the side of resource conservation.

Understanding:
1. Human population growth and consequent demand for resources is inconsistent with resource sustainability.
2. Ecosystem-based management requires time scales that transcend human lifetimes.
3. Ecosystems are open, interconnected, complex, and dynamic; they transcend management boundaries.

What is the Precautionary Approach?

The precautionary principle was developed as a policy measure to address sustainability of natural resources in the face of uncertainty. The principle originated in Germany and has become widely adopted throughout the world in both national and international environmental policies. Nevertheless, the definition of the precautionary principle has remained quite vague, and interpretation has gone to the extremes of complete lack of economic and social considerations in natural resource management.

The elements of the precautionary principle, as suggested by Dovers and Handmer (1995), include:

Definition of the Precautionary Principle. Source: Intergovernmental Agreement on the Environment (1992).

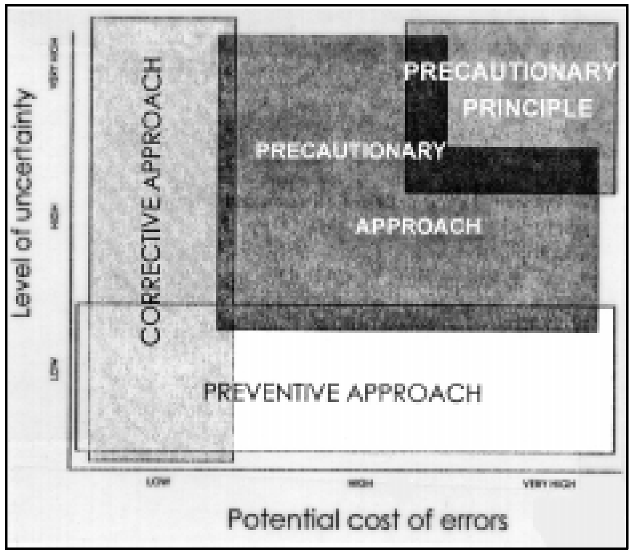
Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by:

(I) careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and
(ii) an assessment of the risk-weighted consequences of various options.

1. *Uncertainty is unavoidable in sustainability issues;*
2. *Uncertainty as to the severity of the environmental impacts resulting from a development decision or an ongoing human activity should not be an excuse to avoid or delay environmental protection measures;*
3. *The principle recommends an anticipatory or preventative approach, rather than a defensive one which simply reacts to environmental damage when it becomes apparent; and*

4. *The onus of proof shifts away from the environment or those advocating its protection, towards those proposing an action that might harm it.*

The precautionary principle should be applied particularly when there is a high level of uncertainty and there are large (potentially irreversible) costs if a mistake is made. In most other cases, sustainable management of fisheries may require a combination of less extreme approaches. The sources and nature of uncertainty, it potential consequences and cost if errors are made, and its potential reversibility should all be considered when determining the management approach to take. Garcia (1995) illustrates these approaches in relation to the level of uncertainty and potential cost of errors, as shown in the adjacent figure.



As defined by Garcia (1995), these approaches include the preventative approach, the corrective approach, the precautionary approach, and the precautionary principle. The **preventative approach** is to avoid the occurrence of unwanted consequences. This approach is used when there is a high degree of scientific knowledge, measures can be designed with a high probability of success, and is fully reversible. The preventative approach is appropriate for micro-scale issues (such as improving gear selectivity, vessel safety regulations, compliance, etc.). The **corrective approach** is to effectively correct for unintended consequences of previous actions. This approach is used when the cost of potential errors is negligible and the consequences are reversible or acceptable. Progress is assumed to occur through "trial and error", with no long term risk. The corrective approach is also suitable for micro-issues such as gear selectivity, closed seasons, and in some cases annual TACs. The **precautionary approach** is to reduce the probability of terrible consequences happening. This approach is used when uncertainty and potential costs are high and full reversibility may not be ensured. The precautionary approach is used to address meso-issues such as resources sustainability, recruitment overfishing, and protection of endangered species. The **precautionary principle** aims to avoid irreversible damage in cases of high uncertainty or ignorance. This approach should be used when reversibility is highly unlikely. The precautionary principle is suitable for application in fishery management when dealing with species introductions, the potential destruction of critical habitats, or any other situation where scientific theories are not yet formed or are controversial (e.g., global warming and ozone depletion).

Fisheries management around the world had traditionally been based on the preventative and corrective approach, yet the collapse of some fisheries indicates that a more precautionary approach should have been applied. The precautionary approach is now integral to the UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks, and has been incorporated into the FAO International Code of conduct for Responsible Fisheries (see adjacent box).

The NPFMC's Ecosystem Committee guidelines for effective ecosystem-based management states that the Council should "use precaution when faced with uncertainties to minimize risk; management decisions should err on the side of resource conservation". The precautionary principle was applied to the ABC/OFL definitions adopted under Amendment 44. The new definitions clearly separate intended catch targets from absolute catch limits, lower harvest rates for depleted stocks, and require greater caution in the presence of uncertainty. For further information on uncertainty and harvest rates for North Pacific Groundfish, refer to Thompson (1997).

Guidelines for using the precautionary approach to fisheries management. Source: FAO Code of Conduct for Responsible Fisheries.

- In order to reduce the risk of damage to the marine environment and living aquatic resources, the precautionary approach should be widely applied.
- In applying the precautionary approach, fisheries management authorities should take into account, inter alia, uncertainties with respect to the size, productivity and state of the stocks, management reference points, levels and distributions of fishing mortality and the impact of fishing activities on associated and dependent species including discard mortality, as well as climatic, environmental, social and economic conditions.
- The precautionary approach should be based on the best scientific evidence available and include all appropriate techniques aimed at setting stock-specific minimum standards for conservation and management. Fishery management authorities should be more cautious when information is poor. They should determine precautionary management reference points and apply precautionary measures consistent with management objectives.
- When precautionary or limit reference points are approached, measures should be taken to ensure that they will not be exceeded. These measures should where possible be pre-negotiated. If such reference points are exceeded, recovery plans should be implemented immediately to restore the stocks.
- In the case of new or exploratory fisheries, conservation measures, including precautionary catch or effort limits, should be established as soon as possible in cooperation with those initiating the fishery should remain in force until there are sufficient data to allow assessment of any increase in fishery intensity on the long-term sustainability of stocks and associated ecosystems.

Selected Precautionary Approach Literature

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Kirkwood, G.P., and A.D.M Smith. 1995. Assessing the precautionary nature of fishery management strategies. Precautionary Approach to Fisheries. Part 2: Scientific Papers. FAO Fisheries Technical Paper. No. 350, Part 2:141-158.

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What are the Plan Team's Specific Ecosystem Concerns?

As in previous years, there are a number of specific ecosystem concerns that the Council and NMFS should consider in the process of setting the 1998 groundfish TACs. While the Teams are not able to provide quantitative recommendations, these concerns suggest serious consideration of more conservative management choices wherever those options exist. Listed below are the team's ecosystem concerns for 1998; the list is not prioritized.

1. **Fishery Effects on Species Composition** -- Large differences exist in the harvest rates of groundfish species off Alaska--some are harvested at or close to their F_{abc} levels while others are harvested substantially below them. Walleye pollock, Pacific cod, sablefish, and most of the rockfish species have been harvested at or close to their estimated ABCs since their history of management under the MFCMA. Flatfishes, on the other hand, have been exploited substantially below ABCs in both the BSAI and GOA.

   The abundance of all flatfish species off Alaska (except for Greenland turbot in the Bering Sea) have been very high. In the Bering Sea, for example, the abundance of all flatfishes combined have increased from about 2.8 million t from 1979 to more than 6.7 million t in 1994. Their combined ABCs and TACS for 1994 were 868,400 t and 467,325 t, respectively. This is 46 percent of the full ABC as set by the Council. In reality the catch of these flatfish species totaled less than 270,000 t in 1994; thus, flatfishes were 69 percent of ABC. Because the utilization of the flatfish resources are constrained by bycatch limits for prohibited species (like crabs and Pacific halibut) and lack of commercial value, the catches are much less than ABC. The low catches combined with good recruitment have kept their biomass high; thus creating greater predation pressure on the prey community.

   High biomasses of predator species may have great impacts on the trophodynamics of the marine ecosystem and shift the species composition. The flatfishes are major predators of forage fish (including juvenile pollock) and benthic organisms. Crabs that substantially overlap the fish feeding range would be subject to heavy predation. While more is known about crab-fish interactions, other crustacean resources, like shrimp, may also have been negatively impacted by high abundance of flatfishes.

2. **Impacts of Fishing Gear on Habitat and Ecosystems** -- The Teams are concerned about the effects of fishing are on seafloor habitats and trophic dynamics, and the Teams support continued research on this question. There are numerous papers on this subject published in the literature, and a summary is provided as a section in this years Ecosystems Considerations chapter. Some research has shown that bottom trawling and other gear types can alter the bottom structure, sediments, and nutrient cycling in certain situations. Other studies have shown little, if any, long term effects.

3. **Localized Depletion: temporal and spatial aspects of fish removals** -- If fish removals are disproportionately high relative to available biomass, localized depletions of the target stock may occur. For example, new research has indicated that trawling can cause localized depletion of Atka mackerel when fishing effort targets on that species (Fritz 1996). The patterns of CPUE observed suggest that the Atka mackerel fishery can have significant impacts on local fish abundances which may remain for weeks after the fishery has left the area. Given the uncertain status of Atka mackerel abundance and recruitment ,and efforts to recover Steller sea lions, temporal and spatial aspects of fish removals be considered more fully in setting ABCs, managing fisheries, and recovering protected species. Concerns have been raised about the amount of pollock currently being removed

from Steller sea lion critical habitat in the Bering Sea. About 60% of the pollock catch has come from critical habitat areas in recent years (see section on "Options for Steller Sea Lion Recovery"). The Bering Sea team heard anecdotal reports about the fishing patterns for pollock in the Aleutian Islands, suggesting that removals may occur in a relatively small area over a very short time period. The team discussed apportioning the AI pollock ABC among subareas to address this concern, and requested more information for next years assessment.

4. **Climatic Changes** -- This draft has included a section on "ecosystem change" and ongoing research on the subject. Shifts between warm and cool eras appear to occur on a decadal or greater (e.g., 18.6 years) frequency in the North Pacific Ocean. Such shifts in physical conditions may also be associated with changes in ocean productivity. Oceanic conditions and the productivity of a variety of plankton, nektonic fish and cephalopods has been hypothesized. Year class strengths of commercially important species have also been related to oceanic temperature conditions. A review dating back to 1948 of 23 fish stocks indicates that 43% of them had more frequent strong year classes during a particular type of ocean temperature regime (e.g., warm or cold). A somewhat longer time scale relationship has also been hypothesized for salmon. Compelling links between ocean conditions and production can be seen in strong year classes of a number of Bering Sea fish stocks (pollock, Pacific cod, Pacific herring) spawned at the onset of warm current regimes (1976-77) that are accompanied by apparent simultaneous decline in stocks of some other finfish (e.g., capelin, shrimps, and king crabs).

   Decreases in marine mammal and increases in the arrowtooth flounder population have been previously discussed. However, evidence is now accumulating of large decreases in the abundance of forage fish and fish eating seabirds in the GOA. Because of the apparent changes in the ecosystem components, the Plan Team encourages the Council to consider a broader look when setting TACs for individual species.

5. **Forage Fish Species** -- Based upon concerns expressed on this issue in 1996, the Council recently adopted a plan amendment to prohibit target fisheries on forage fish species in both the GOA and BSAI. As opportunities to harvest pollock decrease in the Gulf of Alaska, for example, the potential for displacement of fishing effort into new fisheries may increase. The development of new fisheries on underutilized species is not to be discouraged; however, significant changes in exploitation of forage fish, for example, may exacerbate efforts to manage declining populations of non-target species such as Steller sea lions and harbor seals. This amendment is now out for secretarial review.

   Declines of some North Pacific seabirds have largely been ascribed to reduced availability of forage fish. Seabirds feed on walleye pollock (exclusively 0-and 1-class fish), herring, and several other forage fish species. Seabirds depend on an adequate abundance and diversity of fish prey in the vicinity of each breeding colony; one or two forage species may be critical in each location. Prey availability near colonies varies due to current and other abiotic factors, but prey is probably most reliable when overall forage stocks are large. A prohibition of target fisheries on forage fish species would help to prevent increases in seabird mortality or breeding failures.

6. **Seabird Bycatch** -- Bycatch of seabirds in groundfish fishing gear was approximately 10,000 birds in 1993. Ninety percent of the birds taken were taken on longliners. The greatest concern is for the endangered Short-tailed Albatross. If more than four short-tailed Albatross are caught in two years, the longline groundfish fishery could be shut down under Section 7 of the ESA. Measures to deter seabirds from approaching longline gear have been required for Alaskan groundfish fisheries since

April 1997; the plan teams recommend similar regulations for the halibut fishery. Populations of other species are not known to be affected adversely by fishing gear, however reducing overall seabird bycatch also would minimize the chance of future population problems in these species.

7. **Marine Mammal Trends** -- The Plan Teams identified several fishery concerns relevant to the continuing decline of Steller sea lions in the BSAI and GOA. One was diet diversity of sea lions. Discussion included within this report suggests that sea lions need a variety of prey available, perhaps as a buffer to significant changes in abundance of any single prey. The need to maintain a variety of prey for sea lions was the rationale for the BSAI Plan Team proposing that the AI pollock fishery be constrained as a bycatch only fishery. Atka mackerel in the Aleutian Islands area is the primary summer prey for sea lions in the area. As the sea lion population is continuing to decline in the Aleutian Islands, the Council should also consider sea lion concerns when setting a TAC for Atka mackerel for the Aleutian area.

   Finally, the Plan Teams wishes to note that a variety of near shore and pelagic areas have been identified as important foraging habitat for a variety of marine mammal and seabird species. Three of these are of particular concern--Steller sea lions (endangered/threatened under the ESA), red-legged kittiwakes (designated a sensitive species by the USFWS), and northern fur seals (depleted under the MMPA). As the Council considers the BSAI pollock allocation this year, concerns for the health of the populations of these and other species' foraging habitats should also be considered.

   There is a listing of the species that are designated as threatened or endangered under the ESA in the Ecosystems Consideration Chapter. In addition to listing species under the ESA, the critical habitat of a species must be designated concurrent with its listing to the "maximum extent prudent and determinable". In compliance with this require of the ESA, NMFS has designated critical habitats for the Steller sea lion on August 27, 1993. These critical habitats include all rookeries, major haul-outs, and specific aquatic foraging habitats of the BSAI and GOA. The designation of these critical habitats continues for the 1998 fishing year.

   The 1994 reauthorization of the Marine Mammal Protection Act (MMPA) provided for a long-term regime for managing marine mammal takes in commercial fisheries, replacing the Interim Exemption Program that had provided a general exemption on the MMPA take prohibition since 1988 for Alaska's groundfish fisheries. The cornerstone of the new regime is the calculation of Potential Biological Removals (PBRs) for each marine mammal stock. A list of the PBRs for all the marine mammal stocks off Alaska has been contained in previous ecosystem chapters. The PBRs, the level of human caused mortality, and the overall status of the marine mammal stock are to be used to prioritize management of marine mammal/fisheries interactions.

   The overall goal of the management regime is to eventually reduce the levels of marine mammal incidental takes to levels approaching zero. This goal requires a coordinated approach with fisheries management and may involve formation of Take Reduction Teams. For instance, a team may be formed to address all Alaskan marine mammals, including Stellar sea lions. Note, however, that current levels of marine mammal takes in the groundfish fisheries are already quite low. Reduction of subsistence takes exceeding PBRs will be approached through co-management of the resources with Alaska natives.

Compilation of Meetings, Symposia, and Publications Relating to Natural Resource Management of the North Pacific Ocean Large Marine Ecosystem[1]

There are numerous indications that others besides the North Pacific Fishery Management Council family have noticed and are reacting to apparent changes and concerns about the North Pacific. A compilation of new legislation, meetings and publications is provided below. The list is likely not all inclusive.

- The North Pacific Fishery Management Council chartered an Ecosystem Committee to advise the Council on ecosystems level forces applying to fishery management in the federal waters off Alaska.
- The National Research Council released the book *The Bering Sea Ecosystem*, 1996, National Academy Press.
- The United Nations declared 1998 as *International Year of the Oceans* early in 1997. NOAA is expected to take a lead role.
- A El Niño Surface Oscillation (ENSO) background meeting on climate anomalies was held July 11, 1997, in San Francisco.
- Under the Coastal Zone Management Act, NOAA awarded the State of Alaska Division of Governmental Coordination and the St. Paul Coastal District a Section 309 grant to promote interagency cooperation, investigate the feasibility of developing an ocean management plan for the Bering Sea, and develop annotated bibliographies about ecosystem management and local knowledge. A workshop for stakeholders may be held in the spring of 1998.
- A paper, *Bering Sea Ecosystem--A Call to Action* A White Paper, was released by the Department of the Interior August 5, 1997.
- The National Academy of Sciences appointed the NMFS Ecosystem Principles Advisory Panel to work on a report to Congress on *Uses of Ecosystem Approaches in Fisheries Management*. Their first meeting was in September 1997. The report is due in 1998.
- Senator Stevens added an amendment to the DOI and Related Agencies 1998 Appropriations Act that will establish an $800 million endowment fund with oil and gas revenues related to settlement of the Dinkum Sands case (117 S.Ct. 1888). Twenty percent of the interest from the endowment shall be made available to the Secretary of Commerce for the purpose of carrying out marine research activities related to environmental changes in waters off Alaska. The North Pacific Research Board will be established to set marine research priorities.
- The Oceans Act of 1997 was introduced in September 1997 at a press conference on Capital Hill. The Act sets up a Commission on Ocean Policy and a National Ocean Council. The Commission is to report to the President and the Congress on a comprehensive national ocean and coastal policy by reviewing and suggesting changes to current laws and regulations.
- The Center for Marine Conservation (non-governmental organization) sponsored a *Bering Sea Ecosystem Workshop* for representatives from academia, natural resource management agencies, Alaska Natives organizations, and the environmental community to identify and discuss ecosystem-based management issues on Oct. 5-7, 1997, in Anchorage.
- A Lowell Wakefield Fisheries Symposium on *Fishery Stock Assessment Models for the 21st Century* was held Oct. 8-11, 1997, in Anchorage.
- University of Washington School of Fisheries, Fisheries Research Institute, held a seminar on *The Missing Fish in Bristol Bay, What Happened?* on October 9, 1997, in Seattle.
- State and Federal agency representatives met with Alaska Lt. Governor Ulmer on October 16, 1997, regarding the application for fisheries disaster relief funds for Bristol Bay sockeye under Section 312

[1] Initially prepared October 15, 1997, by NMFS Alaska Region (Tamra Faris, Bill Hines, and Bill Heard). Updated November 14, 1997. National Marine Fisheries Service, P.O. Box 21668, Juneau, AK 99802

(A) of the Magnuson-Stevens Fishery Conservation and Management Act. Preliminary information is federal disaster funds will be awarded.

- The Sixth Annual PICES Meeting and Symposium was held Oct.14-26, 1997, in Pusan, Korea.
- The US/Russia Intergovernmental Consultative Committee (ICC) met Oct. 20, 1997, in Vladivostok, Russia. Discussions included ecosystem level changes in shared fish populations.
- A second ENSO Workshop was held Oct. 28, 1997, at the NOAA Pacific Marine Environmental Laboratory in Seattle.
- The North Pacific Anadromous Fish Commission Annual Meeting was held Oct. 27-31, 1997, in Victoria, B.C. Canada. The agenda included the 1997 discrepancy between forecast and realized salmon runs in Bristol Bay.
- The National Marine Fisheries Service and Department of Interior are co-chairing the *Bering Sea Ecosystem Workshop*, to inventory the existence and availability of resource databases on Dec. 4-5, 1997, in Anchorage.
- Another Lowell Wakefield Symposium is scheduled on *Ecosystem Considerations in Fisheries Management* for Sept. 30-Oct. 3, 1998, in Anchorage.
- Senator Hollings introduced S. 1213, a bill that would establish a national ocean policy. This bill, co-sponsored by Senator Stevens, would establish a National Ocean Council of high-level federal staff and a Commission on Ocean Policy composed of 15 members from federal and state agencies, industry, universities and public interest organizations..
- The World Wildlife Fund pledged 10/31/97 that it will spend $10 million protecting the Bering Sea and four other ecoregions identified as the most endangered in the nation.

ESSENTIAL FISH HABITAT

by Jeff Fujioka

In 1996, the Sustainable Fisheries Act amended the Magnuson-Stevens Fishery Conservation and Management Act to require the description and identification of essential fish habitat (EFH) in fishery management plans (FMPs), adverse impacts on EFH, and actions to conserve and enhance EFH. Draft guidelines are being developed by the National Marine Fisheries Service (NMFS) to assist Fishery Management Councils (Councils) in fulfilling the requirements set forth by the Act. In addition, the Act requires consultation between the Secretary and Federal and state agencies on activities that may adversely impact EFH for those species managed under the Act. It also requires the Federal action agency to respond to comments and recommendations made by the Secretary and Councils.

After reviewing the best available scientific information, and in cooperation with the Councils, participants in the fishery, other agencies, and other interested parties, NMFS is to develop written recommendations for the identification of EFH for each FMP. Prior to submitting a written EFH identification recommendation to a Council for an FMP, the draft recommendation will be made available for public review and at least one public meeting will be held. NMFS will work with the Council to conduct this review in association with scheduled public Council meetings whenever possible. The review may be conducted at a meeting of the Council committee responsible for habitat issues or as a part of a full Council meeting. After receiving public comment, NMFS will revise its draft recommendations, as appropriate, and forward written recommendation and comments to the Council(s).

An Alaska Region EFH Core Team was designated to begin coordinating efforts to accomplish the necessary tasks. One of the first things the Core Team did was initiate preliminary Essential Fish Habitat Assessment Reports, summarizing available environmental and fishery data sources relevant to the managed species that may be useful in describing and identifying EFH. This was accomplished by identifying Technical Teams for the Groundfish, Crab, Scallop, and Salmon FMP's from Core Team members and experts from NMFS and ADFG. Synopses from representative species were provided by respective experts from AFSC and ADFG. These reports summarize what is known about each species biology and distribution by major life stage. They also help to identify major species-specific habitat data gaps, which are prevalent in Alaska. In addition to defining EFH from species distribution and requirements, the report will contain a section on a complementary approach to identifying EFH from habitat factors. Sections on adverse impacts and actions to conserve and enhance EFH will also be included. Preliminary EFH assessment reports are expected to be completed in November 1997, with final reports due April 1998. These reports will form the basis for management actions taken to conserve and enhance essential fish habitat in the Alaska region.

Description and identification of EFH

NMFS Draft guidelines indicate that all FMPs must describe EFH in text and with tables that provide information on the biological requirements for each life history stage of the species. The guidelines also indicate that EFH be identified in FMP's by geographical limits, at a minimum, maps of essential habitat of major life history stages. The guidelines also indicate that a tiered approach be used to gather and organize the data necessary for identifying EFH and suggest that Councils should strive to obtain data sufficient to describe habitat at the highest level of detail (i.e., a Level 4). Early in the process, Alaska scientists pointed out there are many species life stages, other than the freshwater stages of salmon and exploitable stages of groundfish, for which the information level is less than the lowest level conceived by the NMFS draft guidelines - ability to establish presence/absence distributions. While an additional lower level was not added, the text for level 1 was broadened to allow for extrapolating sparse knowledge in inferring EFH.

> (1) Level 1: Presence/absence distribution data are available for some or all portions of the geographic range of the species. At this level, only presence/absence data are available to describe the distribution of a species (or life history stage) in relation to existing and potential habitats. Care should be taken to ensure that all habitats have been sampled adequately. In the event that distribution data are available for only portions of the geographic area occupied by a particular life history stage of a species, EFH can be inferred on the basis of distributions among habitats where the species has been found and on information about its habitat requirements and behavior.

Classification of EFH levels used in Alaska groundfish EFH reports based on available information. Note that this classification system differs slightly from the NMFS guidelines.

Level 0	No systematic sampling has been conducted for this species and life stage; may have been caught opportunistically in small numbers during other surveys.
Level 1	Presence/absence distribution data are available for some or all portions of the geographic range.
Level 2	Habitat-related densities are available. Density data should reflect habitat utilization, and the degree that a habitat is utilized is assumed to be indicative of habitat value.
Level 3	Habitat-related growth, reproduction, or survival rates are available. The habitats contributing the most to productivity should be those that support the highest growth, reproduction, and survival of the species (or life history stage).
Level 4	Habitat-related production rates are available. Essential habitats are those necessary to maintain fish production consistent with a sustainable fishery and a healthy ecosystem.

Because of the significant level of data needed to establish presence/absence distributions, compared to the actual level of knowledge for many pre-adult stages of marine species in Alaska, the Core Team used a level 0 in summarizing knowledge levels for species life stages in the preliminary EFH Assessment Reports. Level 0 designates the subset of level 1 for which data is not available to establish presence/absence distributions. This is the most prevalent designation for pre-adult stages of marine species, such as groundfish and scallops.

Research Needs

Each FMP should contain recommendations, preferably in priority order, for research efforts that the Councils and NMFS view as necessary for carrying out their EFH management mandate. The need for additional research is to make available sufficient information to support a higher level of description and identification of EFH. Additional research may also be necessary to identify and evaluate actual and potential adverse effects on EFH.

The Groundfish Technical Team has discussed research needs to describe and identify EFH based on their review of the Habitat Assessment Reports. They identify a need to identify and map marine habitat types, noting the lack of information on habitat preference and availability. The Team also notes that nearshore areas where many juvenile marine fish reside are undersurveyed, resulting in the prevalence of level 0 and 1 tiers of knowledge in the Habitat Assessment Report for pre-adult stages of fish such as sablefish, pollock, rockfish, and flatfish, as well as adult stages of species such as Atka mackerel, Pacific cod, and some of the rockfishes. To increase knowledge levels and obtain valid identification of EFH in nearshore areas, increased sampling for fish distribution and habitat utilization must be conducted.

The EFH Core Team was also tasked with advising the Region on project proposals and spending plans for EFH funds. In early October four Alaska proposals were forwarded to the NMFS Habitat Office for consideration for competitive funding (no priority): 1) improve capability to type bottom habitat with acoustic and video technology, 2) describe demersal spawning and egg nesting habitat of Atka mackerel, 3) nearshore habitat utilization of juvenile marine fish, 4) characterization and mapping of juvenile king crab habitat in E. Bering Sea. In addition, a preliminary overall spending plan for EFH funds was drafted subject to revision after determination of competitive funded proposals.

With the goal of rationalizing the development of spending plans and proposal evaluation, the Core Team also drafted Strategic Investment Frameworks for Groundfish and Salmon EFH. In the draft, the stated goal is "unimpaired habitat for production of maximum sustainable stocks . . .". Four objectives in somewhat logical progression are:

I. Describe EFH for managed species.
- mandated, and may serve the purpose of evaluating knowledge level and increasing public concern.

II. Identify species' life history phases that are vulnerable to habitat alterations.
- for e.g., show that at risk habitat is an important spawning or rearing habitat for an important species.

III. Manage man's alterations of habitat to control impacts.
- for e.g., conduct effective tracking or review of projects and activities and provide effective consultation and permitting to minimize habitat impairment.

IV. Where habitat has been impaired, develop and implement recovery programs.
- for e.g., develop and demonstrate methods to restore habitat function.

For groundfish, where for most species little is known about life history, or even where early life stages reside, it was obvious to the Team that Objective II deserved emphasis. For salmon, where the critical freshwater life history phase and it's habitat requirements are identified, it was recognized that emphasis could progress to Objective III to protect known critical habitat or to Objective IV with habitat that has already been impaired. Additional products or objectives of EFH activities, such as increasing public awareness and concern would serve to improve the ability to attain Objectives III and IV.

THE EFFECTS OF FISHING GEAR ON BENTHIC COMMUNITIES

by Ivan Vining, Dave Witherell, and Jon Heifetz

In recent years, there has been a growing awareness and concern about the effects of resource extraction on ecosystems. Fishery managers around the world are beginning to incorporate, or at a minimum acknowledge, the effects of fishing on marine ecosystems. The groundfish fisheries in Alaska are no exception. Concern has been expressed by scientists, conservationists, fishermen, and others about potential negative effects of fishing gear on bottom habitat, particularly with regard to habitat alteration. In this chapter, we provide a review of scientific studies done to date on the effects of fishing gear on benthic communities of the Gulf of Alaska, Bering Sea, and Aleutian Islands Areas.

Fisheries in the North Pacific are numerous and utilize different gear types. The fisheries and associated gear for the Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska fisheries (GOA) are listed in the adjacent table. Federal regulation § 679.2 specifies the following authorized gear types: dive, fixed gear, hook-and-line, jig, longline, longline pot, non-pelagic trawl, pelagic trawl, pot-and-line, scallop dredge, and trawl. In this section, we summarize potential effects only for primary gears used in the groundfish, scallop, and crab fisheries.

Fishing Gear used in the North Pacific, by fishery.

FMP	Fishery	Gear
BSAI and GOA	groundfish	trawl, longline, jig, pot
BSAI and GOA	halibut	longline, hook&line, troll, jig
BSAI and GOA	scallop	dredge
BSAI	crab	pot
non-FMP (State)	salmon	gill net, seine, troll line, fish wheels, or spears
non-FMP (State)	herring	trawl, seine, gill net, pound net
non-FMP (State)	shrimp	pots, trawls
non-FMP (State)	razor clam	shovel, fork
non-FMP (State)	sea urchin	handpicking, aided by diving gear or abalone iron
non-FMP (State)	octopus	pot
non-FMP (State)	abalone	diving gear and abalone iron
non-FMP (State)	sea cucumber	handpicking, aided by diving gear

If the gear, habitat, and communities were homogeneous, studies designed to measure the effect of fishing gear on benthic communities would be much simpler. However, there is heterogeneity in all aspects of fishing, as well as the habitat and communities affected by fishing gear. When studying gear effect, many questions need to be answered, such as: Do all gears have similar effects? How much actual damage is being done? How long will the damage last? How will damage be measured? Does the extent and longevity of damage depend on bottom type? Does the fishing affect all organisms in the community equally? The purpose of this section of the Ecosystems Chapter is to review the completed work or the work in progress to answer some of these questions, and summarize conclusions.

Trawl Gear

Concerns over the effects of trawling are not new, nor limited to the North Pacific. Trawling was an issue, as early as 1350, when it was banned in the United Kingdom to protect fry of fish (de Groot 1984). Since 1938, studies have been conducted on the east coast of Canada and United States, to evaluate possible effects of trawling on the benthic communities (Ketchen 1947; Graham 1955; Messieh et al. 1991). There has also been an extensive investigation in the North Sea by the Netherlands Institute for Sea Research evaluating the effects of beam trawl fisheries on the bottom fauna (BEON-RAPPORT 8 1990; Bergman and Hup 1992). The effects of trawling are also being studied in New Zealand and Australia, with special attention being paid to hard-bottom trawling (Hutchings 1990; Jones 1992).

There are people who considered the negative effect of trawl gear “common sense” and “intuitive”, and have written articles pointing to likely ways the gear is having a negative effect on the environment (Apollonio

1989; McAllister 1991; Russel 1997). The scientific community, in general, also tends to accept that trawling alters the bottom habitat (Auster et al. 1996). The root of the problem and the cause of controversy lies in the definition of “negative effect”, and the degree of change in the benthic habitat or communities before the change is “destructive”.

The otter trawl is the principle gear used in bottom trawl fisheries in the GOA and BS, and advancements in fishing gear and vessel technology have made gear more efficient. These advances mean that heavier nets are dragging over seabeds, and possibly altering the seafloor more than was observed in earlier studies. Also, larger ships, with greater horsepower and larger, stronger nets are exploring and fishing areas not previously available to the industry (Auster et al. 1996). A further consideration is the domestication of the groundfish industry in the GOA and BS since the Magnuson Act of 1976, which changed the character of trawling in Alaska, from large foreign factory vessels to a mixture of a domestic catcher-processors and numerous smaller catcher vessels.

Physical effects of trawling include plowing and scraping the seafloor, resuspension of sediment, and lowering of habitat complexity. Plowing and scraping effects depend on towing speed, substrate type, strength of tides and currents, and gear configuration (Jones 1992). It has been found that otter doors tend to penetrate the substrate 1 cm - 30 cm; 1 cm on sand and rock substrates, and 30 cm in some mud substrates (Krost et al. 1990; Jones 1992; Brylinsky et al. 1994). Another factor which will cause variation in the depth of the troughs made by the otter doors, is the size (weight) of the doors, i.e. the heavier the doors the deeper the trough (Jones 1992). These benthic troughs can last as little as a few hours or days in mud and sand sediments, over which there is strong tide or current action (Caddy 1973; Jones 1992), or they can last much longer, from between a few months to over 5 years, in seabeds with a mud or sandy-mud substrate at depths greater than > 100 m, with weak or no current flow (Krost et al. 1990; Jones 1992; Brylinsky et al. 1994).

Another aspect of plowing and scraping is the alteration done by the footrope. Once again, different types of footropes will cause more or less alteration. Those footropes which are designed to roll over the seafloor (the type generally, on soft bottoms, employed in the GOA and BS), cause little physical alteration, other than smoothing the substrate and minor compression (Brylinsky et al. 1994; Kaiser and Spencer 1996). However, since a trawler may re-trawl the same area several times, these minor compressions can cause a “packing” of the substrate (Schwinghammer et al. 1996). Further compression of the substrate can occur as the net becomes full and is dragged along the bottom.

The trawling of an area can cause resuspension of both inorganic and organic sediments. Churchill (1989) found that trawling can be a significant contributor to the time-averaged suspended sediment load over heavily trawled areas, especially at depths where bottom stress due to tidal and current action is generally weak. In the GOA, there is relatively weak current and tidal action near the seafloor over much of the groundfish fishing grounds, with a variety of seabed types such as gravely-sand, silty-mud, and muddy to sandy gravel, as well as areas of hard-rock (Hampton et al. 1986). The BS has relatively weak currents, on the other hand, with relatively strong tidal action (currents) accounting for up to 95% of all flow as deep as 200 m, with principally gravely-sand and silty-sand seabed (National Research Council 1996).

The reduction in habitat complexity can be examined in two broad categories: 1) small localized changes and 2) larger area changes. The broader area changes refer to the general reductions in habitat complexity with increases in trawling activity (Auster et al. 1996; Schwinghammer et al. 1996). The small localized changes refer to the smoothing of patchy biogenic depressions, and movement of boulders (Auster et al. 1996).

Mortality can be incurred to those organisms incidentally captured (bycatch), and discarded back into the sea. The mortality rate of the bycatch depends on the species, age and size of a species, the type of gear, the time and type of shipboard handling, and the size of the haul, along with ocean and atmospheric conditions (Hill and Wassenberg 1990; Stevens 1990; Fonds 1991;). It is difficult to generalize the fate of bycaught benthic organisms returned to the sea or compare results from different studies on this subject. In addition, studies have only focused on the survival of fish and crab discards.

Several studies have examined the mortality of crabs taken as bycatch in North Pacific trawl fisheries. In one study, a standard sole trawl (with roller gear) in a subarctic area (Bering Sea) caught king and Tanner crabs while fishing for sole, sorted the catch, with the time on deck being between .5-1.5 hours, then placed the crabs in holding tanks for 48 hours; the resulting mortality rate was 79% for king crab and 78% for Tanner crab (Stevens, 1990). Blackburn and Schmidt (1988) made observations on instantaneous mortality of crab taken by domestic trawl fisheries in the Kodiak area. They found mortality for softshell red king crab averaged 21%, hard shelled red king crab 1.2%, and 12.6% for Tanner crab. Another trawl study indicated that trawl induced instantaneous mortalities aboard ship were 12% for Tanner crab and 19% for red king crab (Owen 1988). Fukuhara and Worlund (1973) observed an overall Tanner crab mortality of 60-70% in the foreign Bering Sea trawl fisheries. They also noted that mortality was higher in the summer (95%) than in the spring (50%). Hayes (1973) found that mortality of Tanner crab captured by trawl gear was due to time out of water, with 50% mortality after 12 hours. Natural Resource Consultants (1988) reported that overall survival of red king crab and Tanner crab bycaught and held in circulation tanks for 24-48 hours was <22%. In analyses of groundfish plan amendments, the estimated mortality rate of trawl bycaught red king crab and Tanner crab was assumed to be 80% (NPFMC 1993).

Damage or mortality of benthic organisms can occur due to the passage of the trawl over the seabed without actually catching the organisms. Non-retained organisms may be subject to mortality from contact with trawl doors, bridles, footrope, or trawl mesh, as well as exposure to silt clouds produced by trawl gear. Mortality of fish escaping from trawl codends may range from none to 100%, and may depend on numerous factors, including fish species, tow size and duration, the size and type of mesh used (Sangster 1992). Mortality can occur due to contusions, a build-up of lactic acid, scale loss and mucus removal, and skin damage due to abrasion and collision with net walls (Sangster 1992; Chopin and Arimoto 1995).

Studies of fish escapement mortality have exhibited a wide range of results. Very low escapement mortality was observed for Alaskan pollock under experimental conditions (Efanov and Istomin 1988). Main and Sangster (1988) observed that mortality of haddock passing through a diamond mesh codend exhibited delayed mortality: 33% mortality after 11 days and 82% mortality after 108 days. DeAlteris and Reifsteck (1993) observed escapement mortality of scup (Stenotomus chrysops) to be 0% to 50%, and less than 4% for winter flounder (Plueronectes americanus) tested by an experimental codend. Bergman et al. (1989) studied the mortality of fishes escaping from commercial beam trawls, and observed mortalities of dab (Limanda limanda), plaice, and sole totaled 44%, 15%, and 0%, respectively, after being held in a cage for 24 hours. Van Beek et al. (1989) also studied the mortality of sole escaping from beam trawls, and their results indicated that 40% of the sole died after escaping through the meshes. Mortality of herring (Clupea harengus) escaping from trawl codends can be higher than for groundfish. Suuronen et al. (1992) observed mortality of codend escapees to be very high (85-90%), with most deaths occurring 3-8 days after escape. Another study of herring showed lower mortality (3-30%) for herring escaping from codends (Efanov 1981).

Besides direct mortality from being caught and handled, there will be further mortality due to re-location into unsuitable habitat and predation while returning to the seafloor. This type of mortality will also depend on many conditions, such as depth, type of species, age and size of species, predator concentration and oceanic conditions. Although there are few studies which have considered these sources of mortality, neither re-location nor predation will likely result in 100% mortality (Hill and Wassenberg, 1990).

Similar to the mortality of bycatch, the survival of benthic organisms in the path of the trawl will depend on several factors. The mortality rate will depend on the species, species age and size, the type of gear, the size of the haul, substrate morphology, and ocean conditions. The most severe damage done to benthic organisms by otter trawls is from the trawl doors, especially sedentary organisms that live in the upper 5 cm of the seabed (Rumohr and Krost, 1991). Rumohr and Krost (1991) further found that thin-shelled bivalves such as *Syndosmya alba*, *Mya* sp. and *Macoma calcarea*, as well as starfish sustain heavy damage due to the trawl doors, whereas thick-shelled bivalves such as *Astarte borealis* and *Corbula gibba* were less likely to be damaged. In one another experiment, hard-shelled red king crab were tethered in the path of an Aleutian combination trawl (Donaldson 1990). Only 2.6% of the crabs that were interacted with the trawl, but not retained, were injured, suggesting a low mortality rate. Other organisms found to be affected by the passage of trawls and specifically the trawl doors are diatoms, nematodes and polychaetes (Brylinsky et al. 1994).

The immediate effect of trawling on hard-bottom seabeds can be intense in certain vulnerable habitats. It was found that from a single tow using roller gear, 3.9% of the octocorals and 30.4% of the stony coral were damaged, as well as 31.7% of the sponges (van Dolah et al., 1987). A similar study in Florida, found that 80% of the stony coral and 38% of the soft corals were damaged, as well as 50% of the sponges. However the trawls in this study were a ridged roller gear assemblage (Tilmant 1979). Both of these studies were in sub-tropical areas. No studies were found assessing trawling in temperate or subarctic hard-bottom habitat, however current work on this is being carried out in the GOA (Heifetz 1997).

Although mortality from bycatch or trawl passage appears to be fairly high, for various organisms, some studies have found recolonization can occur over a relatively short time period. Nematodes and polychaetes returned to their pre-trawled levels in less than 7 weeks and diatoms increased in abundance in trawl troughs within 80 days (Brylinsky et al., 1994). Small epibenthic species that have been resuspended can recover to pre-trawl densities in 24 hours (Rumohr and Krost, 1991). The sponges and most of the corals damaged in the hard-bottom studies, returned to their pre-study levels in approximately a year.

One of the principle concerns associated with trawling is the potential effects on benthic organisms that fish depend on for food. At least in the short term, prey items immediately available to fish do not appear to be reduced. Caddy (1973) found that fish and crabs were attracted to the trawl path, presumably to feed on exposed or dead benthos, within 1 hour after fishing. Other studies have also observed increases in scavenging in the wake of beam trawls (Kaiser and Spencer 1994; Kaiser and Spencer 1996a). Furthermore, the densities of some of the species examined in the study, were 30 times greater than outside the trawl tracks. In Kiel Bay (Baltic Sea) it was believed that cod fed extensively on Arctica islandica, which were crushed or broken by trawl doors (Rumohr and Krost 1991; Jones 1992).

Minor short-term changes in individual species distribution are not likely to greatly effect the entire ecosystem, excessively. The ecosystem is in a constant flux, with many natural phenomena making changes to the environment (de Groot 1984; Brylinsky et al. 1994). The specific question is whether fishing causes long-term changes (negative) in the benthic community structure.

There have been changes to benthic communities from trawling due to habitat alteration. The trawl doors may be the most damaging to benthic organisms on a short-term basis. However, even in deep areas where the troughs may be recognized after long periods (5 years), the doors do not likely have an excessive long-term effect on the overall area, because the relatively small trough is between 0.2 - 2 m (Krost et al. 1990; Rumohr and Krost 1991; Brylinsky et al. 1994). The greater long-term damage to the habitat may be caused by the net and footrope, due to their much larger width , at 3 - 166 m (1.5-90 fathoms), with many between 20-50 m (Grahm 1955, Chris Blackburn, Alaska Groundfish Databank, Kodiak, AK, personal communications). The smoothing caused by multiple trawls (as discussed earlier) removes patchy biogenic depressions and moves boulders, both of which are extremely important habitat to juvenile fish and crustaceans (Armstrong et al. 1993; Auster et al. 1996). Multiple trawls in an area also pack down and lower the complexity of the substrate which will likely reduce the exchange capacity and lead to less species diversity (Jones 1992; Kaiser and Spencer 1996b; Schwinghamer et al. 1996). Some studies have concluded that trawling tends to favor fast-growing, fast-reproducing and relatively short-lived (r-selected) species such as polychaetes, at the expense of slow-growing, slow-reproducing and relatively long-lived (k-selected) species such as crustaceans (Reise 1982; de Groot 1984; Kaiser and Spencer 1996b).

Sediment resuspension, as discussed above, has an effect on the benthic communities as well. Increased sediment suspension can cause reduction of light levels on the seabed, smother benthos following resettlement, create anaerobic conditions near the seabed, and reintroduce toxins that may have settled out of the water column (Churchill 1989; Jones 1992, Messieh et al. 1991).

Dredge Gear

Dredging for scallops may effect habitat by causing unobserved mortality to scallops and other marine life, mortality of discards, and modification of the benthic community and sediments. Similar to trawling, dredging places fine sediments into suspension, bury gravel below the surface and overturn large rocks that are embedded in the substrate (NEFMC 1982, Caddy 1973). Dredging can also result in dislodgement of buried shell material, burying of gravel under re-suspended sand, and overturning of larger rocks with an appreciable roughening of the sediment surface (Caddy 1968). A study of scallop dredging in Scotland showed that dredging caused significant physical disturbance to the sediments, as indicated by furrows and dislodgement of shell fragments and small stones (Eleftheriou and Robertson 1992). The authors note, however, that these changes in bottom topography did not change sediment disposition, sediment size, organic carbon content, or chlorophyll content. Observations of the Icelandic scallop fishery off Norway indicated that dredging changed the bottom substrate from shell-sand to clay with large stones within a 3-year period (Aschan 1991). For some scallop species, it has been demonstrated that dredges may adversely affect substrate required for settlement of young to the bottom (Fonseca et al. 1984; Orensanz 1986). Mayer et al. (1991), investigating the effects of a New Bedford scallop dredge on sedimentology at a site in coastal Maine, found that vertical redistribution of bottom sediments had greater implications than the horizontal translocation associated with scraping and plowing the bottom. The scallop dredge tended to bury surficial metabolizable organic matter below the surface, causing a shift in sediment metabolism away from aerobic respiration that occurred at the sediment-water interface and instead toward subsurface anaerobic respiration by bacteria (Mayer et al. 1991). Dredge marks on the sea floor tend to be short-lived in areas of strong bottom currents, but may persist in low energy environments (Messieh et al. 1991).

Two studies have indicated that intensive scallop dredging may have some direct effects on the benthic community. Eleftheriou and Robertson (1992) , conducted an experimental scallop dredging in a small sandy bay in Scotland to assess the effects of scallop dredging on the benthic fauna. They concluded that while dredging on sandy bottom has a limited effect on the physical environment and the smaller infauna, large numbers of the larger infauna (mollusks) and some epifaunal organisms (echinoderms and crustaceans) were killed or damaged after only a few hauls of the dredge. Long term and cumulative effects were not examined, however. Achan (1991) examined the effects of dredging for islandic scallops on macrobenthos off Norway. Achan found that the faunal biomass declined over a four year period of heavy dredging. Several species, including urchins, shrimp, seastars, and polychaetes showed an increase in abundance over the time period. In summary, scallop gear, like other gear used to harvest living aquatic resources, may effect the benthic community and physical environment relative to the intensity of the fishery.

Several studies have addressed mortality of scallops not captured by dredges. In Australia, this type of fishing gear typically harvests only 5-35% of the scallops in their path, depending on dredge design, target species, bottom type, and other factors (McLoughlin et al. 1991). Of those that come in contact with the dredge but are not captured, some elude the passing dredge and recover completely from the gear interaction. Some injuries may occur during on board handling of undersized scallops that are returned to the sea or during gear interactions on the sea floor (Caddy 1968; Naidu 1988; Caddy 1989), and delayed mortality can result from siltation of body cavities (Naidu 1988) or an increased vulnerability to disease (McLoughlin et al. 1991) and predation (Elner and Jamieson 1979). Caddy (1973) estimated incidental dredge mortality to be 13 to 17%, based on observations of broken and mutilated shells of Atlantic sea scallops. However, a submersible study of sea scallops from the Mid-Atlantic indicated that scallop dredges capture with high efficiency those scallops which are within the path of the scallop dredge and cause very low mortality among those scallops that are not captured (NEFMC 1988). Murawski and Serchuk (1989) made submersible observations of dredge tracks and found a much lower mortality rate (<5%) for Atlantic sea scallops. The difference in mortality between these two studies can be attributed to the substrate on which the experiments were conducted. Caddy's work was done in a sandy/gravelly area and Murawski and Serchuk worked on a smooth sand bottom. Shepard and Auster (1991) investigated the effect of different substrate types on dredge induced damage to scallops and found a significantly higher incidental damage on rock than sand, 25.5% versus 7.7%. For weathervane scallops, mortality is likely to be lower, as this species prefers smoother bottom substrates consisting of mud, clay, sand, or gravel (Hennick 1970a, 1973).

Atlantic sea scallop beds and the benthic community associated with scallop fishing grounds in the Bay of Fundy were assessed in 1969 (Caddy 1976). During the intervening years, the area has seen great changes in fishing pressure, with recent effort amounting to more than 90 vessels of over 25 GRT were continuously fishing the grounds with Digby drags for days at a time (Kenchington and Lundy 1991). Since 1969, there have also been dramatic fluctuations in scallop abundance, including both record highs and lows for this century. In particular, scallop abundance rose to over 1000 times "normal" levels with the recruitment of two strong year-classes in 1985 and 1986. This information indicates that extensive dredging does not effect the recruitment of scallops to a productive ground.

Observations from scallop fisheries across the state suggest that mortality of crab bycatch may be lower on average than those taken in trawl fisheries, perhaps due to shorter tow times, shorter exposure times, and lower catch weight and volume. For crab taken as bycatch in the Gulf of Alaska weathervane scallop fishery, Hennick (1973) estimated that about 30% of Tanner crabs and 42% of the red king crabs bycaught in scallop dredges were killed or injured. Hammerstrom and Merrit (1985) estimated mortality of Tanner crab at 8% in Cook Inlet. Kaiser (1986) estimated mortality rates of 19% for Tanner crab and 48% for red king crab bycaught off Kodiak Island. Urban et al. (1994) recorded that in 1992, 13-35% of the Tanner crab bycaught were dead or moribund before being discarded, with the highest mortality rate occurring on small (<40 mm carapace width, CW) and large (>120 mm CW) crabs. Delayed mortality of Tanner crab resulting from injury or stress has not estimated. Mortality in the Bering Sea appears to be lower than in the Gulf of Alaska, in part due to different sizes of crab taken. Observations from the 1993 Bering Sea scallop fishery indicated lower bycatch mortality of red king crab (10%), Tanner crab (11%) and snow crab (19%) (Barnhart et al. 1996). As with observations from the Gulf of Alaska, mortality appeared to be related to size, with larger and smaller crabs having higher mortality rates on average than mid-sized crabs (Barnhart et al. 1996). Delayed mortality was not estimated. In one groundfish plan amendment analysis, a ll sources of crab mortality were examined; in this analysis a 40% discard mortality rate for all crab species was assumed for scallop fisheries (NPFMC 1993).

Adverse effects of scallop dredges on benthic communities in Alaska may be lower in intensity than trawl gear. Studies on effects of trawl and dredge gear have revealed that, in general, the heavier the gear in contact with the seabed, the greater the damage (Jones 1992). Scallop dredges generally weigh less than most trawl doors, and the relative width they occupy is significantly smaller. A 15' wide New Bedford style scallop dredge weighs about 1,900 lbs (Kodiak Fish Co. data). Because scallop vessels generally fish two dredges, the total weight of the gear is 3,800 lbs. Trawl gear can be significantly heavier. An 850 HP vessel pulling a trawl with a 150' sweep may require a pair of doors weigh that about 4,500 pounds each. Total weight of all trawl gear, including net, footrope, and mud gear would weigh about 16,400 lbs (T. Kandianis, personal communication). Hence, based on weight of gear alone, scallop fishing may have less effect than bottom trawling.

Longline Gear

Very little information exists regarding the effects of longlining on benthic habitat. Observations of halibut longline gear made by NMFS scientists during submersible dives off Southeast Alaska provide some information (NPFMC 1992). The following is a summary of these observations: "Setline gear often lies slack on the sea-floor and meanders considerably along the bottom. During the retrieval process the line sweeps the bottom for considerable distances before lifting off the bottom. It snags on whatever objects are in its path, including rocks and corals. Smaller rocks are upended, hard corals are broken, and soft corals appear unaffected by the passing line. Invertebrates and other light weight objects are dislodged and pass over or under the line. Fish, notably halibut, frequently moved the groundline numerous feet along the bottom and up into the water column during escape runs disturbing objects in their path. This line motion was noted for distances of 50 feet or more on either side of the hooked fish."

Some crabs are caught incidentally by longline gear in pursuit of groundfish, and a portion of these crabs die. No field or laboratory studies have been made to estimate mortality of crab discarded in longline fisheries. However, based on condition factor information from the trawl survey, mortality of crab bycatch has been estimated and used in previous analyses (NPFMC 1993). Discard mortality rates were estimated at 37% for red king crab and 45% for C. bairdi Tanner crab taken in longline fisheries. No observations had been made for snow crab, but mortality rates may be similar to Tanner crab.

Mortality of groundfish discarded in longline fisheries has not been studied extensively in Alaska. Studies with Pacific halibut have shown that discards may have high mortality if not released carefully from hooks. Additionally, some species such as rockfish do not survive changes in pressure when they are hauled up quickly from the bottom. Mortality of discarded halibut has been estimated to be about 15% for most longline fisheries (Williams 1997).

Pot Gear

Pot gear is used in the North Pacific to harvest crabs and groundfish. This gear type likely effects habitat during the process of setting and retrieving pots; however, no research has been conducted to date.

Like other fisheries, pot fisheries incur some bycatch of incidental fish and crab. The groundfish pot fishery targets Pacific cod, but takes other species such as crab and flatfish, which are discarded. Mortality of bycaught fish in groundfish pot fisheries has not been studied, with the exception of Pacific halibut. Based on viability data, it has been estimated that mortality of halibut bycaught in groundfish pot fisheries averages about 7% (Williams 1997). Bycatch in crab pot fisheries includes crabs, octopus, Pacific cod, halibut, and other flatfish (Tracy 1994). Crab bycatch includes females of target species, sublegal males of target species, and non-target crab.

There are a variety of effects caused by handling, ranging from sublethal (reduced growth rates, molting probabilities, visual acuity from bright lights, and vigor) to lethal effects. Several laboratory and field studies have been conducted to determine mortality caused by handling juvenile and female crab taken in crab fisheries. Studies have shown a range of mortality due to handling based on gear type, species, molting stage, number of times handled, temperature, and exposure time (Murphy and Kruse 1995). Handling mortality may have contributed to the high natural mortality levels observed for Bristol Bay red king crab in the early 1980's (65% for males and 82% for females), that along with high harvest rates, resulted in stock collapse (Zheng et al. 1995). However, another study concluded that handling mortality was not responsible for the decline on the red king crab fishery (Zhou and Shirley 1995a). Byersdorfer and Watson (1992, 1993) examined red king crab and Tanner crab taken as bycatch during the 1991 and 1992 red king crab test fisheries. Instantaneous handling mortality of red king crab was <1% in 1991, and 11.2% in 1992. Stevens and MacIntosh (1993) found average overall mortality of 5.2% for red king crabs and 11% for Tanner crabs on one commercial crab vessel. Authors recommend these results be viewed with caution, noting that experimental conditions were marginal. Mortality for red king crab held 48 hours was 8% (Stevens and MacIntosh 1993, as cited in Queirolo et al. 1995). A laboratory study that examined the effects of multiple handling indicated that mortality of discarded red king crabs was negligible (2%), although body damage increased with handling mortality (Zhou and Shirley 1995a).

Delayed mortality of crabs due to handling does not appear to be influenced by method of release. In an experiment done during a test fishery, red king crab thrown off the deck while the vessel was moving versus those gently placed back into the ocean showed no differences in tag return rates (Watson and Pengilly 1994). Handling methods on mortality has been shown to be non-significant in laboratory experiments with red king crab (Zhou and Shirley 1995a, 1995b) and Tanner crab (MacIntosh et al. 1995). Although handling did not cause mortality, injury rates were directly related to the number of times handled.

Mortality of crabs is also related to time out of water and air temperature. A study of red king crabs and Tanner crabs found that crabs exposed to air exhibited reduced vigor and righting times, feeding rates (Tanner crabs), and growth (red king crabs) (Carls and Clair 1989). Cold air resulted in leg loss or immediate mortality for Tanner crabs, whereas red king crabs exhibited delayed mortality that occurred during molting. A relationship was developed to predict mortality as the product of temperature and duration of exposure (measured as degree hours). Because BSAI crab fisheries occur during November through February, cold exposure could cause significant handling mortality to crabs not immediately returned to the ocean. However, Zhou and Shirley (1995) observed that average time on deck was generally 2 to 3 minutes, and they concluded that handling mortality was not a significant source of mortality.

Current Research in the North Pacific

There are several studies being conducted to specifically assess the effect of trawling on the seafloor, benthic organisms and their habitat. In 1996, the Alaska Fisheries Science Center (AFSC) initiated a number of sea floor habitat studies directed at investigating the effect of fishing on the sea floor and evaluation of technology to determine bottom habitat type. A summary of the accomplishments of each of those projects is included below. In 1997, four of the projects were continued and one new project initiated. The accomplishments of the FY 1996 studies are:

Experimental Trawling in the Eastern Gulf of Alaska. A chartered manned submersible and chartered commercial trawl vessel were used to quantify changes to the sea floor caused by bottom trawling. Specific objectives were to document changes to epifauna and physical attributes to the sea floor caused by bottom trawling with tier-gear. The experiment took place in the Eastern GOA in rockfish habitat over hard bottom substrate during July and August 1996. Video footage was obtained from 10 trawl paths, including seven single tow paths, two triple tow paths and one seven tow path. Analysis of the videotape data is focusing on habitat classification, sessile and motile epifauna in trawled versus untrawled transects, damage to epifauna, and comparisons of trawl bycatch with organisms in situ. Study sites were marked so that observations could be repeated in 1997.

Trawl Effects in the Eastern Bering Sea. Experimental trawling was conducted in the BS to improve our understanding of the effects of bottom trawls on the soft-bottom benthos. Samples were collected with a NMFS 83-112 bottom trawl modified to improve retention of epifauna. In this study, epifauna are assumed to be indicators of sea floor attributes, given characteristically strong affinities for particular substrates. An historical analysis of commercial bottom trawl effort in the BS (1933-95) identified adjacent pairs of heavily fished and unfished 1 nmi^2 areas of the sea floor. Population densities and community structure in the two groups of stations will be compared. A color video system was attached to the experimental trawl and provided additional information on habitat features. In addition to inferences about trawl-related effects, this research will provide important information about the spatial variability in benthic communities and will serve as the basis for more rigorous manipulative investigations in the future.

Retrospective Analysis of Commercial Trawl Data and Benthic Community Structure. Commercial trawl fishery data and trawl survey data will be used to determine the structure of benthic communities and possible trawl fishery effects on these communities. The objectives of this study will be to 1) describe the geographic and temporal patterns of trawl fishery effort in the GOA and Aleutian Island (AI) regions, 2) describe the major benthic communities by their component species and associations based on trawl survey data, and 3) to the extent possible, determine possible trawl fishery influences on benthic community structure by comparing benthic community structure in heavily trawled areas to lightly trawled areas. This study will be carried out via a grant to the Cooperative Institute for Arctic Research (CIFAR) at the University of Alaska, Fairbanks (UAF). This study will produce documentation of the extent and location of past trawling activities and infer possible effects on benthic communities.

Evaluation of Technology to Determine Bottom Habitat Type. Habitat typing technologies may be useful in documenting effects of fishing on sea floor habitats. Laser line scan systems (LLSS) and hydroacoustic bottom typing systems were used in areas that have been ground truthed. Data collected with LLSS was compared with historical (1991-1995) video and side scan sonar imagery over a well known area of bottom at depths similar to where trawl fisheries commonly occur. Also the feasibility of using LLSS to detect trawl tracks on the sea floor was evaluated. Trawl tracks were difficult or impossible to observe in well sorted sand mixed with shell hash, more easily observed in sand/silt mud bottom and clearly observable in soft bottom. The LLSS appears to fill a gap between side scan sonar and ROVs, is easily deployed and capable of observing some effects of trawling. An acoustic bottom typing system (QTC View Series 3, manufactured by the Quester Tangent Corporation, Sidney, B.C.) was used to begin an evaluation of the efficacy of remote sensing of sea floor properties in soft bottom areas of the BS and hard bottom areas of the GOA.

Workshop on Potential Effects of Fishing Gear on Benthic Habitat. About 30 individuals participated in the workshop including scientists from RACE, REFM and ABL Divisions of the Alaska Fisheries Science Center, NMFS Alaska Regional Office, U.S. Geological Survey, Alaska Department of Fish and Game (ADF&G), University of Alaska Fairbanks (UAF), University of Washington (UW), and the National Undersea Research Center. The primary objectives of this workshop were to review the progress and preliminary results of studies initiated in 1996 and to discuss approaches and priorities for proposed research for 1997. Presentations included preliminary observations from a manned submersible of trawl effects on hard bottom areas in the Eastern GOA, an overview of field studies to examine bottom trawl effects in the BS, a description of methods to be used to examine benthic community structure and possible effects of trawling based on historical data in the GOA and AI, and video footage of how different types of trawl gear can effect seafloor habitats. Additional presentations included a review of fishing gear effects studies off the northeast United States and preliminary evaluations of the feasibility of using laser line scan systems, sidescan sonar, and hydroacoustic habitat mapping systems as research tools to examine fishing gear effects. Abstracts from this workshop are found in Heifetz (1997).

While the current studies being carried out in FY 1997:

Continuation of trawling effect studies in the Eastern Gulf of Alaska. Objectives: 1) assess recovery of sea floor habitats at experimental sites that were trawled in 1996 and 2) assess feasibility of examining effects and recovery of benthic epifauna (primarily gorgonian coral, Primnoa sp.) in high profile hard-bottom substrate in the vicinity of southeast Alaska.

Continuation of retrospective analysis of commercial trawl data and benthic community structure in the GOA and AI. Objectives: 1) Describe the geographic and temporal patterns of trawling effort in the GOA and AI region; 2) describe the major benthic assemblages by component species and associations; and, 3) determine possible trawl fishery influences on benthic community structure by comparing attributes of communities in heavily trawled areas to lightly trawled areas. This study will be carried out via an extension of a grant to the CIFAR at the UAF.

Continuation of trawling effect studies in the Eastern Bering Sea. Objectives: 1) determine if trawls have measurable effects on benthic habitats in the BS; 2) if negative effects are identified, examine the recovery rate in affected areas; and, 3) as a precursor for future work, use side-scan sonar and/or video surveys to examine the heavily fished "cod corridor" in the vicinity of Unimak Pass.

Continuation of evaluation of hydroacoustic technology for sea floor classification. Objectives: 1) evaluate the technical feasibility of hydoracoustic sea floor classification to enable habitat mapping during routine NMFS surveys; and, 2) produce habitat classification catalogs for use in the Eastern BS and GOA.

Effects of trawling on hard bottom habitat in Seguam Pass in the AI. Gorgonian corals were once a major component of the bycatch of the Atka mackerel fishery in Seguam Pass in the Aleutian Islands. However, after twenty years of intense fishing effort coral is now infrequently caught. Objectives: 1) examine whether the corals in the heavily trawled areas of Seguam Pass are more damaged and less abundant than in nearby, less trawled, areas; and, 2) investigate whether fish and invertebrates use coral forests for shelter. The first year of his project will be devoted to design, construction, and testing of the live- feed video towed body that will be used in this research.

CONCLUSIONS

Alterations to natural communities are inevitable when harvesting marine organisms with any gear type. The removal of any organism has , by itself, an effect. Furthermore, some studies have shown that the community will return to relatively pristine conditions in a relatively short time period following a fishing closure, if there was an affect at all (Graham 1955; van Dolah et al. 1987; Rumohr and Krost 1991; Jones 1992; Brylinsky et al. 1994). On the other hand, there is also the suggestion that pre-fishing, "pristine", conditions are not known, since almost all study areas have had some form of fishing prior to the study (Auster et al. 1996). Lastly, there are also studies that conclude that trawling, in some situations, may cause long-term changes in habitat and community structure (Auster et al. 1996; Kaiser and Spencer 1996b; Schwinghamer et al. 1996).

To further confuse the issue, nothing is static. The fishing industry makes regular alterations to gear and fishing techniques. The oceanic, and atmospheric conditions change continually, on both local and global scales, all of which may affect groundfish or the benthic communities upon which they depend. Lastly, other human induced actions such as pollution, mining and petroleum exploration can affect benthic communities as well. However, declines of some fisheries being observed around the world have served to emphasize that all sources of potential effects should be considered by managers aiming for sustainability.

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BIOLOGICAL FEATURES

Seabirds - by Vivian Mendenhall

Status and trophic relationships of seabirds

Alaska supports North America's greatest concentration of seabirds, owing to its productive marine waters and abundant nesting habitat. Approximately 38 seabird species nest in Alaska, including 36 million birds at 470 colonies in the BS/AI and 12 million birds at 20,000 colonies in the GOA. In addition, up to 50 million shearwaters and 3 albatross species feed in Alaskan waters but breed farther south. Characteristics of seabird biology include delayed maturity, long life, low reproductive rates, and dependence on the sea as their source of food.

Status of populations.--Some seabird populations in the Bering Sea/Aleutian Islands and Gulf of Alaska regions have declined during part or all of the past 2 decades. Most declines were concentrated on islands of the southeastern Bering Sea and in the northern Gulf of Alaska. The principal colony of the Red-legged Kittiwake on St. George Island declined by almost 50% from 1975 to 1989 (Hatch et al. 1993), but has since stabilized (Byrd and Dragoo 1997). Several other species on the Pribilof Islands declined between 1975 and 1985, but have since stabilized or increased (see adjacent box). In the northern Gulf of Alaska, declines have been documented in several species, including Pigeon Guillemots and Marbled Murrelets (Hatch et al. 1993; Klosiewski and Laing 1994; Kuletz 1996; Oakley and Kuletz 1996; Piatt and Anderson 1996). These declines probably began before the *Exxon Valdez* oil spill. Populations in other areas generally have been stable or have increased (reviewed in Hatch and Piatt 1995; Francis et al. 1996).

Seabird trends in the North Pacific, from Byrd and Dragoo (1997).

Species	Location	Trend
Northern Fulmar	St. Paul I.	Increasing
	St. George I.	Increasing
Black-legged Kittiwake	Cape Lisburne	Stable
	St. Paul I.	Stable
	Cape Peirce	Decreasing
	Bluff	Stable
	St. George I.	Increasing
	Buldir I.	Increasing
Red-legged Kittiwake	St Paul I.	Stable
	St. George I.	Stable
	Buldir I.	Increasing
Common Murres	St. Paul I.	Increasing
	St. George I.	Increasing
	Cape Peirce	Stable
	East Amatuli	Stable
Thick-billed Murres	Cape Lisbur	Increasing
	St. Paul I.	Stable
	St. George I.	Stable
	Buldir I.	Increasing

One seabird species that enters Alaskan waters, the Short-tailed Albatross, is endangered. The entire world population in 1995 was estimated as 800 birds; 350 adults breed on two small islands near Japan (H. Hasegawa, pers. comm.). The population is growing but is still critically endangered because of its small size and restricted breeding range. NMFS has consulted with the U.S. Fish and Wildlife Service (USFWS) concerning possible impacts of groundfish fisheries on Short-tailed Albatross populations, as required by the Endangered Species Act. USFWS has issued a Biological Opinion that permits a small incidental take of Short-tailed Albatrosses (as of February 1997, the permitted take is 4 birds in two years). Bycatch of albatrosses is discussed further below.

Most population trends in high-latitude seabirds have been associated with changes in food availability (Birkhead and Furness 1985; Piatt and Anderson 1996). Other threats can affect seabird populations locally. The most serious of these in Alaska has been (and remains) the introduction of alien predators, both foxes (Bailey 1993) and rats from vessels (Loy 1993). Oil spills may cause declines in some colonies, but even the *Exxon Valdez* spill may have affected populations less than changes in food supply and habitat (Hatch and Piatt 1995, Piatt and Anderson 1996).

Trophic relationships.--Seabirds obtain their food at sea by picking prey from the surface or by diving and pursuing it underwater. Forage fish are the principal diet of more than two thirds of Alaskan seabird species (reviewed in NPFMC 1996). Capelin and sandlance are crucial to many bird species; other forage fish include Myctophids, herring, Pacific saury, and walleye pollock. Many seabirds can subsist on a variety of invertebrates and fish during nonbreeding months but can raise their nestlings only on forage fish (Sanger 1987; Vermeer et al. 1987).

Seabird population trends are largely determined by forage fish availability (Birkhead and Furness 1985). Although seabirds are adapted to occasional years of poor reproduction, a long-term scarcity of forage fish leads to population declines, usually through breeding failure rather than adult mortality. Seabirds depend on forage fish that are small (5 to 20 cm), high in energy content, and form schools within efficient foraging range of the breeding colony. Seabirds such as kittiwakes and terns can take prey only when they are concentrated at the surface. These species are affected more frequently by food shortage than are diving seabirds such as murres, murrelets, puffins, and cormorants.

Although Alaskan seabirds consume several species of fish, only one or two forage species are available near most colonies. If an important fish stock is depleted locally, birds may have no alternative and breeding fails (Springer 1991).

Ecological interactions between seabirds and fisheries

Overview--Fisheries and seabirds compete for forage fish, but this interaction is difficult to evaluate. Climatic fluctuations cause major fluctuations in seabird food resources (Wooster 1993), but fisheries also contribute to some forage fish trends (Duffy 1983; Steele 1991). Pollock and herring are the only food species of Alaskan seabirds for which there are large directed fisheries. The pollock fishery may have impacted this food source by temporarily depleting local forage concentrations on which breeding birds depend near their colonies (Francis et al. 1996). There may also have been indirect ecosystem effects on other forage species (Francis et al. 1996; Piatt and Anderson 1996). Direct impacts on important seabird forage species in most parts of Alaska, such as capelin and sand lance, would be prevented by regulations that would prohibit directed fisheries for these species. The regulations were submitted to the Secretary on 31 October 1997.

Fisheries and seabirds may interact through the food chain in other ways. Fish processing provides food directly to scavenging species such as Northern Fulmars and large gulls. This can benefit populations of some species, but it can be detrimental to others which gulls may displace or prey upon (Furness and Ainley 1984). Impacts of seabird predation on fish populations have variously been estimated as minor to significant (reviewed by Croxall 1987).

The ways in which food availability for seabirds is determined by fluctuations in fish stocks are still very incompletely understood. However, understanding of these ecosystem processes is beginning to improve at present.

Current research--Several ongoing projects are beginning to expand our knowledge of seabird-fish relationships. This is possible because of new levels of cooperation among NMFS, USFWS, other agencies, and universities. (1) The Seabird, Marine Mammal, and Oceanography Coordinated Investigations (SMMOCI) is investigating how seabird populations are limited by local forage fish dynamics at six breeding colonies in Alaska (Byrd et al. 1997). (2) The Alaska Predator Ecosystem Experiment (APEX) is a five-year study of bird-fish relationships in Prince William Sound and the northern GOA (Duffy 1997). APEX will include multi-species modeling of fish, birds, other ecosystem components, and fisheries. The project is being funded by the *Exxon Valdez* Oil Spill Trustees Council. (3) Seabird-forage relationships in the Bering Sea are the subject of the FOCI project of NMFS and the University of California at Irvine, with funding by PISCES/GLOBEC (Decker et al. 1995). All projects are revealing that seabird species are affected in different ways by changes in their forage species.

Bycatch of seabirds

Overview--Seabirds are caught incidentally to all types of fishing operations. However, longlines are more hazardous to birds than other groundfish gear. Longlines catch surface-feeding seabirds as they attempt to capture baits during setting of the line. Some birds are caught on hooks and drown. Some take of birds also occurs in trawls and pots, and through striking the superstructure of vessels. Inshore fisheries also take seabirds. Gillnets catch both surface-feeders and diving birds (Wynne et al. 1991, 1992); bycatch in seines has been reported anecdotally but never investigated.

Bycatch of seabirds in groundfish fisheries has been monitored by fishery observers since 1990. Since 1993, observers have been trained by USFWS identify birds to genus or species. Birds found in the observers' random samples are reported on standard bycatch forms; in addition, Short-tailed Albatrosses are reported whenever they are caught. A preliminary rough estimate of average annual mortality of seabirds in groundfish fisheries (Wohl et al. 1995) is 9,600 birds.

Current developments--NMFS, USFWS, and the Biological Resources Division of the U.S. Geological Survey (BRD; formerly National Biological Service) are currently cooperating in an in-depth analysis of bird bycatch data. At present (November 1997), data for both reported bycatch and total commercial harvest have been downloaded to USFWS and are undergoing a final error-check. Methods for estimating total bycatch are being developed jointly by NMFS and USFWS. Estimates of total bycatch should be available within a few months.

Three Short-tailed Albatrosses were reported caught in the longline fishery since 1990: two in 1995 and one in October 1996. Both 1995 birds were caught in the vicinity of Unimak Pass and were taken outside the observers' statistical samples; the 1996 bird was caught near the Pribilof Islands in an observer's sample. USFWS, NMFS, and BRD are cooperating to develop an estimate of total bycatch, based on this extremely small sample of observed bycatch. USFWS and NMFS also are cooperating to construct a computer model the Short-tailed Albatross population, with the help of the Japanese expert Dr. Hiroshi Hasegawa, to evaluate the impact of bycatch on the population. The model is currently being refined, based on input from Dr. Hasegawa in September 1997.

Measures to deter birds from approaching longline gear have been required for Alaskan groundfish fisheries since April 1997. Similar regulations are being drafted for the halibut fishery. Fishers are contributing to the development of deterrent devices for Alaskan waters, as provided for in the regulations. NMFS is currently designing a study to document the effectiveness of various deterrent devices in Alaskan waters.

International concern for bycatch of seabirds in longline fisheries has led to mitigation measures also being required for Antarctic waters (by the Commission for the Conservation of Antarctic Marine Living Resources and by NMFS), and for some other waters of the Southern Hemisphere (by the Commission for the Conservation of Southern Bluefin Tuna). Many other nations will soon address the problem through the Committee on Fisheries of the Food and Agriculture Organization (FAO) . The FAO is convening a

Technical Working Group to develop guidelines for of all nations to reduce bycatch of seabirds in longline fisheries. The guidelines will be considered for adoption by the FAO in 1999. The group is expected to include representatives of agencies, industry, and other groups from several nations, including the U.S. Meetings began in September 1997 in Anchorage and will continue during 1998 in Japan.

Die-off of seabirds in Alaska in summer 1997

An extensive seabird die-off occurred in Alaska in summer 1997. Larger than normal numbers of dead birds were reported on beaches and the water from both sides of the Alaska Peninsula to Adak, Bristol Bay, the Chukchi Sea, and even Anadyr (Russia). Only a few species were affected: Short-tailed Shearwaters, Black-legged Kittiwakes, and murres. All other species, with a few localized exceptions, apparently were unaffected.

Short-tailed Shearwaters died throughout the area, from the end of July to late August. Other species died in some regions: Black-legged Kittiwakes on the Alaska Peninsula in early August, and murres and some other species in small parts of the west and north from May through August. Mortality lasted about a week in each area. Total mortality may never be known but probably exceeded 100,000.

This die-off was very widely reported, considering that the entire area has no roads and few human residents. Calls came from villagers, fishermen, onshore processors, and diverse biologists. Ground surveys were conducted on 21 beaches and aerial surveys on four. Cooperators sent specimens from 20 locations. Information was received and coordinated by USFWS. Local reports provided invaluable data on the timing and extent of the die-off.

Numerous reports were received of birds behaving unusually. Flocks of shearwaters were seen feeding much closer to shore than usual. Shearwaters and kittiwakes were attempting to grab food from fishing gear and vessels. Flocks commonly included moribund birds that did not fly at the approach of a vessel. Dead birds were emaciated and light in weight; autopsies revealed no bacterial or viral diseases. All these things suggest that starvation was the cause of death.

The seabird die-off apparently resulted from unusually warm waters in the Gulf of Alaska and Bering Sea. Explanations are derived from a combination of ongoing research and educated guesses. Shearwaters in eastern Bristol Bay were unable to find concentrations of euphausiid zooplankton ("krill") on which they usually depend (G.L. Hunt, pers. comm.). Upwellings that usually provide nutrients to the plankton were absent in that area for part of summer 1997, so the plankton did not grow and multiply normally there. Warm surface waters may cause some forage fish to descend to deeper layers. Diving birds can still obtain fish under such conditions, but surface-feeding birds such as kittiwakes cannot (Baird 1990). Factors that may have contributed to this die-off are still being investigated through analysis of field data from several parts of the state.

Several substantial seabird die-offs have been reported in Alaska in the past. Murres died along the north side of the Alaska Peninsula in April 1970 (Bailey and Davenport 1972); Short-tailed Shearwaters, Black-legged Kittiwakes, and other species died in the Gulf of Alaska and Bering Sea in summer 1983, a year of strong El Nino effects (Hatch 1987); and murres died in the northern Gulf of Alaska in February 1993 (Piatt and Van Pelt 1997). All were ascribed to starvation as a result of unusual sea conditions. None of the past die-offs has been found to reduce breeding populations of seabirds in Alaska significantly. Seabird populations may be more severely affected by gradual, long-term changes in food resources than by short-lived extremes in sea conditions.

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Marine Mammals - by John Sease and Rich Ferrero

Status of harbor seals--Minimum population estimates were obtained for harbor seals, *Phoca vitulina richardsi*, in the Gulf of Alaska region along the south side of the Alaska Peninsula, Shumigan Islands, Cook Inlet, Kenai Peninsula and the Kodiak Archipelago during August and September 1996. The mean number of seals counted was 10,595 with a 95% confidence interval between 9,993 and 11,197. The CV of the mean was equal to 2.9%. This represents an increase of 4,259 seals when compared to the mean count from similar surveys in 1992. However, at least 1,392 seals were counted in areas not described in 1992. Aerial survey conditions were exceptionally good in 1996, unlike 1992. At selected major sites (>100 seals) from all areas surveyed in both years, 11 of 20 sites increased and 7 decreased. The overall trend was positive. Approximately 846 more seals (18%) were counted in 1996 at these 20 sites. Seal counts between 1992 and 1996 were nearly identical in the fringe areas, but increased toward the center of the range, the Kodiak Archipelago. By far the largest increase occurred at Tugidak Island, which increased from 770 seals in 1992 to 1,345 in 1996. Seal counts at Tugidak Island, even though increasing, still represent an 80% decline over counts made in 1976.

Harbor seal surveys were conducted from Yakutat to Frederick Sound in Southeast Alaska during August and September 1997. Data analysis is not completed at this time.

Status of Steller sea lions--On 4 May 1997, the NMFS published a Final Rule (62 FR 24345) that formally separated the Steller sea lion population into eastern and western stocks and listed the western stock as "endangered" under the ESA. The eastern stock remains listed as "threatened." The two stocks are separated at 144°W, or approximately at Cape Suckling, just east of Prince William Sound. This stock separation was based on genetic differences (mitochondrial DNA), different population trajectories (declining stock in the west, stable or slightly increasing stock in the east), as well as other factors. The listing became effective on 4 June 1997. No additional management actions accompanied the change in listing. Instead, the NMFS/AKR and the NMFS/AFSC are re-examining existing protective measures to assess their efficacy.

An Alaska-wide aerial survey for Steller sea lions was not scheduled for 1997 (beginning in 1992, aerial surveys have been on an alternate-year schedule). However, the NMFS/AFSC did conduct a partial survey during 10-14 June, which covered the central and western Gulf of Alaska and the eastern Aleutian Islands. Specifically, the 1997 survey included rookery and haul-out sites from Outer Island off the Kenai Peninsula to the Umnak Island region. Protocols and methods were the same as for previous June aerial surveys. Numbers of non-pups at rookery and haul-out trend sites in the three-region area declined by 13.9% since 1994 and 10.3% since June 1996 (Table 1). The greatest relative declines were in the central Gulf of Alaska (Kenai Peninsula to the Semidi Islands), a region where non-

Table 1.--Counts of **adult and juvenile (non-pup)** Steller sea lions observed at rookery and haulout trend sites and estimated annual rate of change for three regions of Alaska surveyed during June 1994, 1996, and 1997.

Area	Number of sites	Counts of non-pups 1994	1996	1997	Percent change 1994-97	1996-97
Gulf of Alaska						
Central	15	4,520	3,915	3,352	-25.8	-14.4
Western	9	3,982	3,741	3,633	-8.8	-2.9
Aleutian Islands						
Eastern	10[1]	3,694	4,057	3,520	-4.7	-13.2
3-Region total	34[1]	12,196	11,713	10,505	-13.9	-10.3

[1]Totals for each survey do not include rookeries at Bogoslof and Adugak islands, which were obscured by fog and not surveyed in 1997.

pup numbers have declined each survey since 1989. Numbers also declined at trend sites in the western Gulf of Alaska and in the eastern Aleutian Islands, two regions where numbers had been stable or increasing since 1989. Considering all sites surveyed each year since 1994 (approximately 50% more animals than at trend sites only), numbers of non-pups remained stable in the western Gulf and eastern Aleutian Islands (10,858 in 1994, 11,034 in 1996, 11,080 in 1997).

The NMFS and ADF&G counted sea lion pups at 14 rookeries during June-July 1997 (Table 2). The 4 rookeries on Attu, Agattu, and Buldir islands in the western Aleutians had not been counted previously by NMFS, thus there are no comparable data for analysis. In the central Aleutians, pup numbers increased by 25% at Kasatochi since the last count in 1994; the increase at Seguam-Saddleridge was equivocal. Pup counts Bogoslof and Ugamak islands in the eastern Aleutians are essentially unchanged from 1994/1995 to 1997, although the count at Ugamak Island in 1996 was greater by more than 100 pups. Numbers of pups at Forrester Island have been stable for several years. Pup numbers at the 2 other rookeries in Southeast Alaska, and for Southeast Alaska in general, continue to increase.

Table 2--Numbers of Steller sea lion **pups** counted at rookeries during June-July 1997 and estimated annual percent change from previous counts. Corresponding counts from previous years are not available for rookeries at Attu, Agattu, and Buldir islands.

	Pup counts			Percent change	
Rookery	1994	1996	1997	1994-97	1996-97
Aleutian Islands					
Attu-Cape Wrangell	-		222	-	-
Agattu-Gillon Point	-		258	-	-
Agattu-Cape Sabak	-		379	-	-
Buldir	-		120	-	-
Kasatochi	215		268	+24.7	-
Seguam	444		463	+4.3	-
Bogoslof	282[1]		281	< 1	-
Ugamak	574	706	589	+2.6	-16.6
Southeast Alaska					
White Sisters	151	182	205	+35.8	+12.6
Hazy Islands	862	768	1,157	+34.2	+50.7
Forrester	2,757	2,764	2,798	+1.5	+1.2
Southeast total	3,770	3,714	4,160	+10.3	+12.0

[1] Bogoslof Island pup count from 1995.

Anomalous oceanographic conditions were observed in the Bering Sea and Gulf of Alaska by the fishing fleet and by oceanographic research vessels during summer 1997. These observations included unusually mild weather, vertical stratification of the water column, warm surface water, and an unusual plankton bloom. In many areas of the Bering Sea, hundreds of surface-feeding seabirds (especially shearwaters) died, presumably of starvation. The NMML sea lion research cruise encountered unusually warm surface water in parts of Unimak Pass. It is not known if these unusual conditions affected numbers of non-pups or pups observed during the aerial survey and pup counts.

OPTIONS IN STELLER SEA LION RECOVERY AND GROUNDFISH FISHERY MANAGEMENT

by Lowell W. Fritz and Richard C. Ferrero

The decline in the Steller sea lion population has been attributed to a reduction in the survival of juvenile sea lions and subsequent depression of recruitment (Merrick et al. 1987; Loughlin and Merrick 1989; NMFS 1992; Trites and Larkin 1992; Pasqual and Adkison 1994; York 1994). The specific causes of increased rates of juvenile mortality, however, remain unclear. During the period of steepest decline (1985-89), Loughlin (1987) assembled a list of potential causes and rated their relative impacts (Table 1). Through analysis of available data as well as research conducted since the listing in 1990, seven of the causes in Loughlin's list have been virtually eliminated as primary causes of the decline. These included incidental take in fisheries, the commercial pup harvest of the 1960s and early 1970s, entanglement in marine debris, increased rates of predation, subsistence harvests by Alaska natives, pollution, and harassment. In addition, while disease could greatly affect individual fitness and survival, no evidence suggests that a specific pathogen was responsible for increased juvenile mortality. Consequently, of the remaining possibilities, only intentional takes (e.g., shooting), and changes in prey abundance, composition, or distribution remain viable. Changes in the prey base could stem from shifts in climatic or oceanographic conditions (*natural* change), fishing (*anthropogenic* change), or both (Merrick et al. 1987; Alverson 1992; NMFS 1992; Trites and Larkin 1992; Pasqual and Adkison 1994; NRC 1996).

Table 1. Relative potential impact of causes of the Steller sea lion population decline (from Loughlin 1987).

Cause	Potential Impact
1. Disease	High
2. Combined Impact of All Fishery Effects	High
A. Changes in Prey Abundance or Composition	Moderate
B. Incidental Take	Moderate
C. Intentional Take	Moderate
3. Commercial Pup Harvest	Low
4. Entanglement in Marine Debris	Low for Adults Probably low for Juveniles
5. Increased Predation	Low
6. Climate and Ocean Changes	Low
7. Subsistence Harvest	Low
8. Pollution	Low
9. Harassment	Low

Section 7 of the Endangered Species Act (ESA) requires that federal actions, including commercial fisheries removals within the U.S. Exclusive Economic Zone, are not likely to jeopardize the continued existence of a listed species. The National Marine Fisheries Service (NMFS) Section 7 review of the 1991 proposed quota for walleye pollock in the Gulf of Alaska (GOA) concluded that changes in the temporal and spatial distribution of the pollock fishery may have contributed to the Steller sea lion decline. Specifically, the fishery operated more in fall and winter, caught the quota in less time, and fished more often in areas designated as Steller sea lion critical habitat under the ESA (Figure 1; Fritz et al. 1995; critical habitat for Steller sea lions was designated in 1993).

In response, the North Pacific Fishery Management Council (NPFMC) imposed a series of management restrictions on groundfish fisheries in 1991-93, including: 1) spatial allocation of the quarterly GOA pollock catch quota among three areas in the GOA (Areas 610, 620, and 630); 2) limitation of the amount of unharvested pollock from one quarter that was available for harvest in subsequent quarters (temporal allocation); 3) prohibition of trawl fishing within 10 nm of all sea lion rookeries west of 150° W. (Figure 1); and prohibition of trawl fishing within 20 nm of 6 sea lion rookeries in the eastern Aleutian Islands during the Bering Sea and Aleutian Islands (BSAI) winter pollock roe fishery (Figure 1). The regulatory intent was to disperse trawl fisheries in time and space, exclude them from some important sea lion habitats, and minimize the likelihood that groundfish fisheries would create localized depletions of sea lion prey. In 1993, the NPFMC also spatially allocated the catch quota for Atka mackerel in the Aleutian Islands among three districts (areas 541-543) where similarly increasing spatial compression of the fishery led to concerns about its effects on the long-term recruitment and sustainability of this locally aggregated species. While dispersal of the Atka mackerel quota was initiated to conserve fish, it was also consistent with the objectives of the four fishery management measures enacted for Steller sea lion recovery.

An examination of some recent groundfish fishery data could elucidate any changes resulting from the sea lion-fishery measures enacted in 1991-93. For instance, the spatial distribution of the pollock fishery from 1977-95 would reveal changes in the level of fishing activities in areas utilized by sea lions. In addition, changes in catch per unit effort of the Atka mackerel fishery may show if localized depletions can be related to the fishery. The results of these comparisons may provide a basis for suggesting future management considerations.

Pollock Fishery Distribution

Prior to the enactment of sea lion protective measures (1977-91), pollock landings doubled from Steller sea lion critical habitat in the BSAI (Figures 1 and 2A). While 100,000-300,000 t were caught annually in 1977-86, 400,000-600,000 t were reported from 1987-91. Since 1992, pollock landings from sea lion critical habitat in the BSAI have continued to increase, ranging from 650,000-870,000 t. These landings represent an increase from 10% of the total pollock landings in 1977 to almost 70% in 1995 (Figure 2B). In the GOA, pollock landings from critical habitat increased from trace amounts in 1977-80 to over 220,000 t in 1985 (Figures 1 and 3A), and then declined (as the annual catch quotas declined) to between 43,000-63,000 t through 1992. However, the percentage of total annual GOA pollock catches taken from critical habitat, which increased through 1985, remained between 50% and 90% through 1991 (Figure 3B). Since 1992, there has been no significant change in the annual percentage taken from critical habitat.

The spatial compression of the pollock fishery coincided with the decrease in the annual rate of sea lion population decline. This observation is not intended to denote cause and effect; on the contrary, it is stated as a caution regarding casual correlations of data. If fisheries have an effect on sea lion foraging, it is likely to be more complex than an inverse relationship between sea lion numbers and pollock catches from critical habitat (Ferrero and Fritz 1994).

Recent pollock fishery distribution patterns suggest that interactions with sea lions in critical habitats are ongoing despite the partitioning that was achieved in the vicinity of rookeries. In the GOA, the combination of spatial pollock allocations and trawl exclusion zones may have stabilized pollock removals and effort at 1985-91 levels, but did not reduce them. In the BSAI, where there is only broad regional allocation of the pollock quota between the eastern Bering Sea and Aleutian Islands management areas, the creation of 10 and 20 nm trawl exclusion zones did not constrain landings from important sea lion habitats. Pollock removals from sea lion habitats began increasing prior to 1991-93 (Figure 2A), and it is not known how much the sea lion protective measures may have reduced the rate of increase had they not been enacted. It must be noted, however, that the areas within the existing trawl exclusion zones were not heavily utilized by the BSAI pollock fishery prior to their creation; from 1984-91, the annual percentage of pollock caught within these areas ranged only from 1-7%. Regardless, recent fishery patterns suggest that to reduce fishery activities within sea lion habitats, refinement of the existing regulations is necessary.

Atka mackerel Fishery and Localized Depletions

In-season changes in catch per unit effort (CPUE) of the Atka mackerel fishery in the Aleutian Islands and GOA were analyzed using Leslie's method (as described by Ricker (1975)) to calculate initial stock sizes and harvest rates at four locations (Fritz 1997). Atka mackerel harvest rate estimates (catch divided by the

Leslie estimate of the initial population size) ranged between 55% and 91%, considerably larger than the target harvest rates of between 10% and 15% for the managed populations as a whole (Lowe and Fritz 1996a;b). Evidence from length-frequency distributions and the time-series of CPUE suggested that the exploited populations were not closed, yet the fishery's rates of removal far exceeded rates of immigration. While the origin of the immigrating fish was not known, some may have come from areas within nearby trawl exclusion zones. In one case after a 7-week gap in landings, fishery CPUEs were still only half those observed at the beginning of the season. Regardless of the impact a series of intense, local fisheries may have on Steller sea lion foraging success (which is unknown), these data suggest that they have occurred despite specific management regulations to disperse fishery effort.

Possible Actions

Since it appears that additional steps are necessary to reduce the level of interaction between groundfish fisheries and Steller sea lions, what other options are available to managers? Possible measures can be grouped into three general categories: gear modifications or restrictions, reductions in total catch, and further temporal-spatial control of fishery distributions.

Gear Modifications

Options to promote Steller sea lion recovery through gear modifications could include such items as minimum trawl mesh size requirements or restrictions on the use of particular gear types. Currently, few restrictions are imposed on the gear (i.e., longlines, pots, or trawls) used to catch groundfish, although the NPFMC has considered both mesh size and shape restrictions previously. The objectives of these proposals were to minimize bycatch of small fish and increase fishery efficiency, although benefits to sea lions could theoretically result if less prey were removed. However, the effectiveness of mesh size/shape requirements on reducing small fish mortality is equivocal. This is due to uncertain survival rates of fish escaping through the mesh (Chopin and Arimato 1995) and the reduction in the trawl's selective properties (net plugging) when the catch volume is high (Erickson et al. 1995). In addition and regardless of mesh size/shape, the disturbance effects of many trawls on fish school structure (Nunnalee 1991; Fréon et al. 1992) and sea lion foraging energetics represent unknown, but potentially detrimental factors.

Suggesting changes in gear assumes that certain gear sizes, types, or configurations are responsible for decreased availability of forage for Steller sea lions through either direct removals or by school disruption and disturbance effects. With regard to catches of small fish by groundfish fisheries, there are no data to support that this has decreased prey availability to sea lions. First, Fritz (in press) recently concluded that catches of juvenile pollock by groundfish fisheries have been low, averaging less than 1% of the population of 0-3 year-old pollock each year in both the GOA and BSAI. Second, Livingston (1993) compared the removals of various sizes of pollock by the fishery, marine mammals, birds, and groundfish in the eastern Bering Sea. She concluded that consumption of pollock, primarily as 0-1 year olds, by various groundfish predators far exceeded the amount consumed by marine mammal predators and the fishery. Given their rate of consumption by groundfish, it is unlikely that total removals of small pollock by any currently employed gear type in the groundfish fisheries is significantly restricting the recovery of Steller sea lions.

Similarly, gear modifications to reduce the total amount of bycatch of other small pelagic fishes by groundfish fisheries may not, by themselves, be effective in promoting sea lion recovery. Capelin (*Mallotus villosus*), for instance, has occurred frequently in Steller sea lion diets (Calkins and Goodwin 1988; NMFS 1992). Livingston (1996) estimated that in one year (1990) in the Gulf of Alaska, groundfish consumed approximately 330,000 t of capelin, which greatly exceeds both the historical estimate of capelin consumption by sea lions (18,000 t; Calkins and Goodwin 1988; Livingston 1996) and the average annual amount of capelin bycatch in the GOA groundfish fisheries in 1990-95 (330 t; Fritz, NMFS, unpubl. data). This suggests, as with juvenile pollock, that requiring modifications to groundfish fishery gear, such as a minimum mesh size, to reduce the bycatch of other small pelagic fishes is not likely to significantly increase the amount of those fish available to Steller sea lions.

While the specific configuration of groundfish trawl gear may not represent an important consideration in sea lion recovery, the increasing scale and local intensity of trawl fisheries warrants examination. In the mid-late 1980s, the sizes of trawls used in both the pelagic and bottom trawl groundfish fisheries increased as improvements were made in net design, construction and materials (Laevastu and Favorite 1988). During the early 1980's (foreign and early joint-venture fisheries), mid-water or pelagic trawls used in the pollock fishery generally had openings in the range of 30-50 m wide and 15-30 m high (up to 1,500 m^2 trawl mouth areas) and caught 20-80 t in a single tow. However, trawls used today in the mid-water pollock fishery are up to 100 m wide, 80 m high (up to 8,000 m^2 trawl mouth areas) and 350 m long and can catch as much as 400 t in a single haul. Catch capacities of bottom trawls used to target Atka mackerel have likewise increased.

The cumulative disturbance effect of trawling on fish school structure, sea lion foraging efficiency, and ultimately, prey availability to sea lions is largely unknown. Hydroacoustic observations of the effects of trawling on Pacific whiting (*Merluccius productus*) school structure in Puget Sound, WA suggest that while the school deforms and has a "hole" in it due to removal of fish and their avoidance of the gear, its structure returns relatively quickly (on the order of tens of minutes) to a pre-trawling condition (Nunnallee 1991). The results under commercial conditions, when this process is repeated by many vessels over several days using nets capable of catching hundreds of tons of fish on fish school structure, are not known. However, removals of large numbers of fish alone would be expected to decrease either school density or school size for some period of time. Data on the effects of reduced prey availability (caused by the 1982-83 El Niño) on California sea lion foraging energetics suggest that prey dispersion would likely increase energy expenditure and search time for food (Trillmich and Ono 1991), both disadvantages to Steller sea lion fitness.

Trawls are an efficient means to catch semi-demersal schooling species (e.g., Atka mackerel and pollock), which are not caught effectively by fixed gear (e.g., pots and hook and line). When the trawl exclusion zones were created, the NPFMC considered excluding all gear. Trawls alone were excluded because the risk of lethal incidental take and the likelihood of creating localized depletions of sea lion prey are greater with trawl gear than with fixed gear (e.g., pots and hook and line). Trawls will continue to be a central feature of the groundfish fishery, but means to further mitigate their potential detrimental effects on sea lion foraging deserve consideration.

Reductions in Total Catch

The process of setting groundfish catch quotas is grounded in single species fishery management and population dynamics modeling concepts (Pope 1972; Deriso et al. 1985; Methot 1990; Clark 1991). These procedures emphasize the estimation of total stock size over the managed region (e.g., GOA) and the determination of a fishing mortality rate and catch level that maximizes yield (catch) while not leading to overfishing. In the BSAI and GOA groundfish fisheries, one of the most commonly used methods to determine the target fishing mortality rate involves reducing the biomass per recruit to some fraction (e.g., 40%) of the unfished level (termed the $F_{40\%}$ rate; see Clark 1991).

Using single species models, predation by marine mammals, birds, and other groundfish on the target stock is generally considered only to the extent that it is a component of M, the rate of natural mortality. More explicit accounting for predator removals have been attempted by estimating individual predator consumption rates and extrapolating them to the population level. Following this approach, Kajimura and Fowler (1984) estimated that Steller sea lions, at their pre-1980 level of abundance, consumed about 270,000 t of pollock each year in the eastern Bering Sea. Livingston (1993) and Perez and McAlister (1993), using a smaller sea lion population size and a lower pollock consumption rate, estimated Steller sea lion consumption of pollock at only 56,000 t and 61,000 t, respectively. In an attempt to increase the availability of pollock to Steller sea lions, the catch of pollock could be reduced by 130,000 t (the average of the three consumption estimates), which is approximately 10% of recent Bering Sea pollock catch quotas. While representing a relatively large portion of the pollock quota, this reduction may not significantly increase the availability of pollock to sea lions, since it assumes that every pollock foregone by fisheries would be available to sea lions. These analyses do not consider the geographic or size distribution of the foregone catch, or its ultimate contribution to prey density and availability to foraging sea lions. To actually increase sea lion foraging success, a significantly larger reduction in pollock removals may be necessary, but there is no method of determining how large that reduction should be to be effective.

Another approach to estimating fish removals by predators in stock assessments is to directly incorporate them in the single species modeling process. In Hollowed et al. (1995), pollock removals by Steller sea lions and two major groundfish predators, arrowtooth flounder (*Atheresthes stomias*) and Pacific halibut (*Hippoglossus stenolepis*) were treated as fisheries in the stock synthesis model (Methot 1990), each with their own selectivities and estimated catch biomasses. The results, though preliminary, suggested that total natural mortality had been underestimated (by about 33%) in non-predation versions of the model. If the predation model had been used to set the Catch quota, the target $F_{40\%}$ rate would also have increased. For example, suppose there is a stock that has a natural mortality rate of 0.3, recruits to the fishery at 3 years of age when it has an average weight of 0.5 kg, and increases in weight 0.1 kg each year to a maximum age of 10 years. Fishing at a rate of 0.56 reduces the biomass per recruit of the stock to 40% of its unfished level. Increasing the estimated rate of natural mortality from 0.3 to 0.4 (an increase of 33%) will also increase the $F_{40\%}$ rate from 0.56 to 0.80 (an increase of 43%). Consequently, given that a stock has a high rate of natural mortality, fishing rates can and should also be high to maximize potential yield. However, prey density with respect to the energetic requirements of foraging competitors was not considered in this approach.

Determining the amount to reduce a catch quota to account for sea lion needs and allow for their recovery may not be possible using food habits information alone or within the current single species modeling framework. A quota reduction is a blunt, non-specific instrument used to address a particular problem, in this case, prey availability to sea lions, with no means to monitor its effect. Alternatively, reductions in removals and interactions could be refined by our knowledge of the spatial distributions of predator, prey, and fishery. In this manner, the level of competitive interactions would be reduced the most in areas which are the most important to sea lions.

Temporal-spatial distribution of fishing

Established in 1991-93, trawl exclusion zones around Steller sea lion rookeries created areas near important terrestrial habitats where sea lions can forage relatively undisturbed from the potential effects of trawl fisheries. However, the criterion used to establish trawl exclusion zones, all rookeries west of 150°W, does not accurately reflect current knowledge of seasonal sea lion distributions. Furthermore, it does not consider the distribution of juveniles.

Alaska-wide aerial surveys of Steller sea lions and the tracks of sea lions with satellite transmitters suggested that sea lions spend more time at sea during the winter, forage in much larger areas, and use a different group of sites to haulout than in summer (Merrick and Loughlin, in press). Satellite-tagged females with pups swam more than 200 nm from a haulout while foraging in winter, compared to maximum ranges of about 20 nm in summer. Some terrestrial sites used as rookeries in the summer were abandoned in winter, while some little-used summer haulouts had large sea lion numbers in winter. Differences in breeding and non-breeding season distributions are not reflected in the design of the current set of trawl exclusion zones since the zones were implemented before these differences were known.

If decreases in fishery-sea lion interactions remain as the primary objective of sea lion and groundfish fishery management, then criteria used to establish trawl exclusion zones should be redefined to reflect the seasonal use of terrestrial and marine habitats by different age groups of Steller sea lions. Sites proposed for buffer-zone protection could be based on a minimum number of sea lions counted in surveys (e.g., 200 was used to designate major haulouts as critical habitat) or in combinations which, in aggregate, protect a percentage of the population (e.g., 50%, 75%, or 90%). Additionally, zone diameter could change to reflect the larger foraging ranges observed in winter.

Trawl exclusion zones of modest size (radii of 10-20 nm) reduce groundfish activities in areas surrounding important terrestrial habitats, but will not by themselves reduce fishery-sea lion interactions beyond their boundaries in pelagic foraging areas. For instance, Atka mackerel fisheries in the Aleutian Islands may have reduced local prey densities by as much as two-thirds for several months just outside the zones, and may have "drained" fish from within the zone (Fritz 1997). Consequently, the zones by themselves, while creating a refuge, may not significantly reduce the competitive interactions if there is intense fishing effort immediately outside the zones.

In addition to refinement of the trawl exclusion zones, mechanisms to spatially allocate catch quotas outside of them may be warranted. In the case of Atka mackerel in the Aleutian Islands, the quota could be distributed to a greater number of smaller areas than the three management sub-districts (Figure 1) to reduce the intensity of effort on local aggregations. This will also require changes in the manner in which the stock is assessed. Likewise, for pollock in the eastern Bering Sea, spatial allocation of the quota could reduce the proportion removed from sea lion critical habitat foraging areas (Figure 3) to levels below the proportion of the pollock stock in those areas. While not decreasing the total catch, this would decrease removals and effort in areas important to sea lions. Thus, refinements in our temporal and spatial control of fishing distributions should consider seasonal sea lion distributions and foraging ranges. These, in combination with changes in the implementation of trawl exclusion zones could reduce fishery-sea lion interactions and potentially assist their recovery.

To date, efforts to partition Steller sea lions and commercial fisheries in Alaskan waters have met with some success, although their overall effect on sea lion recovery are not apparent. Nonetheless, the direction of such management efforts may be appropriate given our limited understanding of sea lion-fishery interactions: either more intensified efforts or a longer period may be required before observable changes in the sea lion population occur. Given the depressed status of the sea lion population and the potential for greater changes to the commercial fishing industry should the decline continue, we suggest fishery managers consider the tools available to implement measures which could benefit sea lions. Of the measures discussed, we suggest particular attention be given to further refinement of the trawl exclusion zone strategy and both spatial and temporal reductions in fishery effort in areas identified as critical sea lion habitat. While this will cause changes in the distribution and structure of the Alaskan groundfish fishery, it may be necessary in order to insure its long-term viability.

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Figure 1. Location of trawl exclusion zones around Steller sea lion rookeries and areas designated as sea lion critical habitat west of 144°W under the Endangered Species Act.

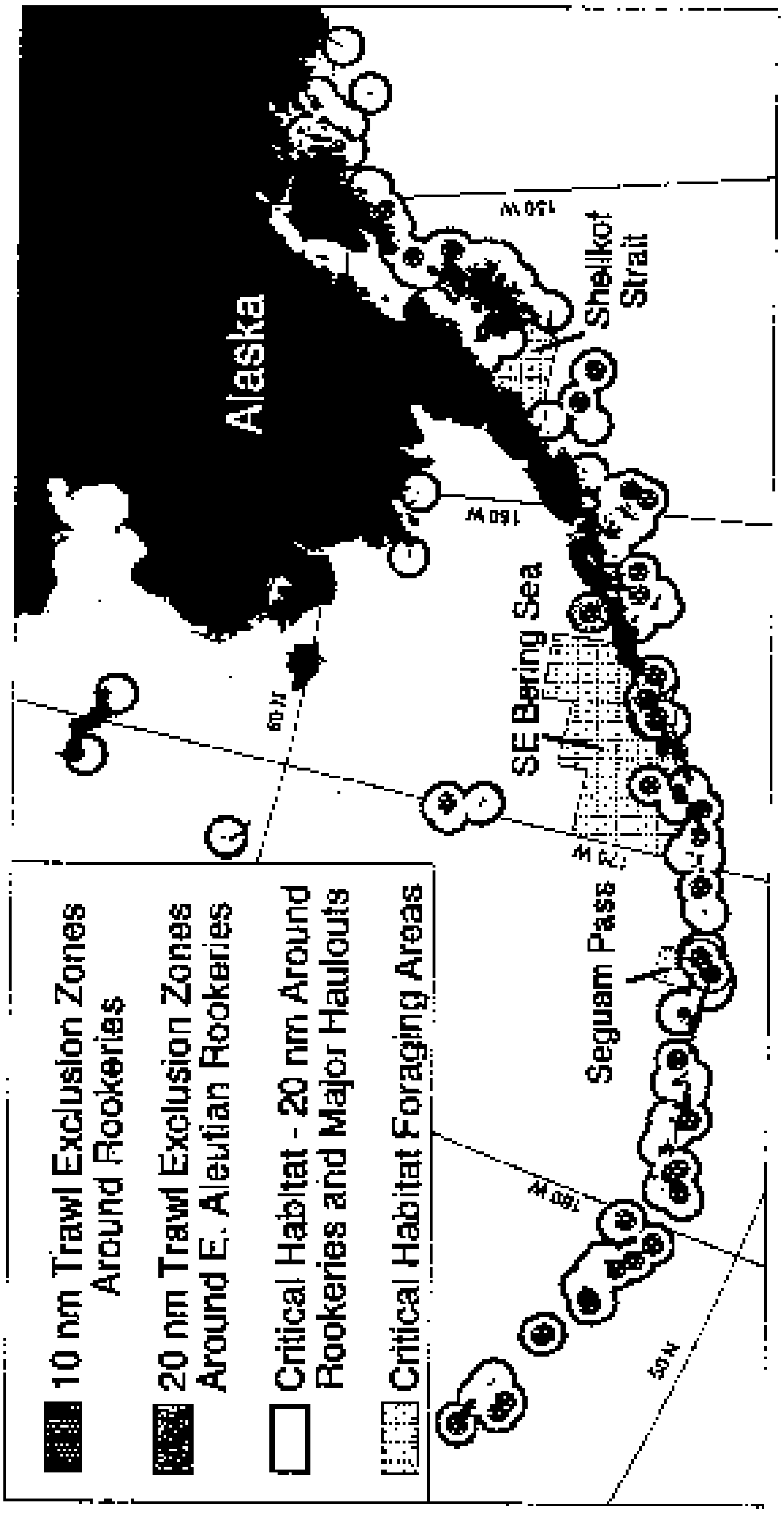


Figure 2. Pollock catch within Steller sea lion critical habitat in the eastern Bering Sea and Aleutian Islands (BSAI), 1977-1995. A. Tons of pollock caught within critical habitat. B. Percent of annual BSAI pollock catch from critical habitat. Years when sea lion protective measures were in place are lightly shaded (1992-1995).

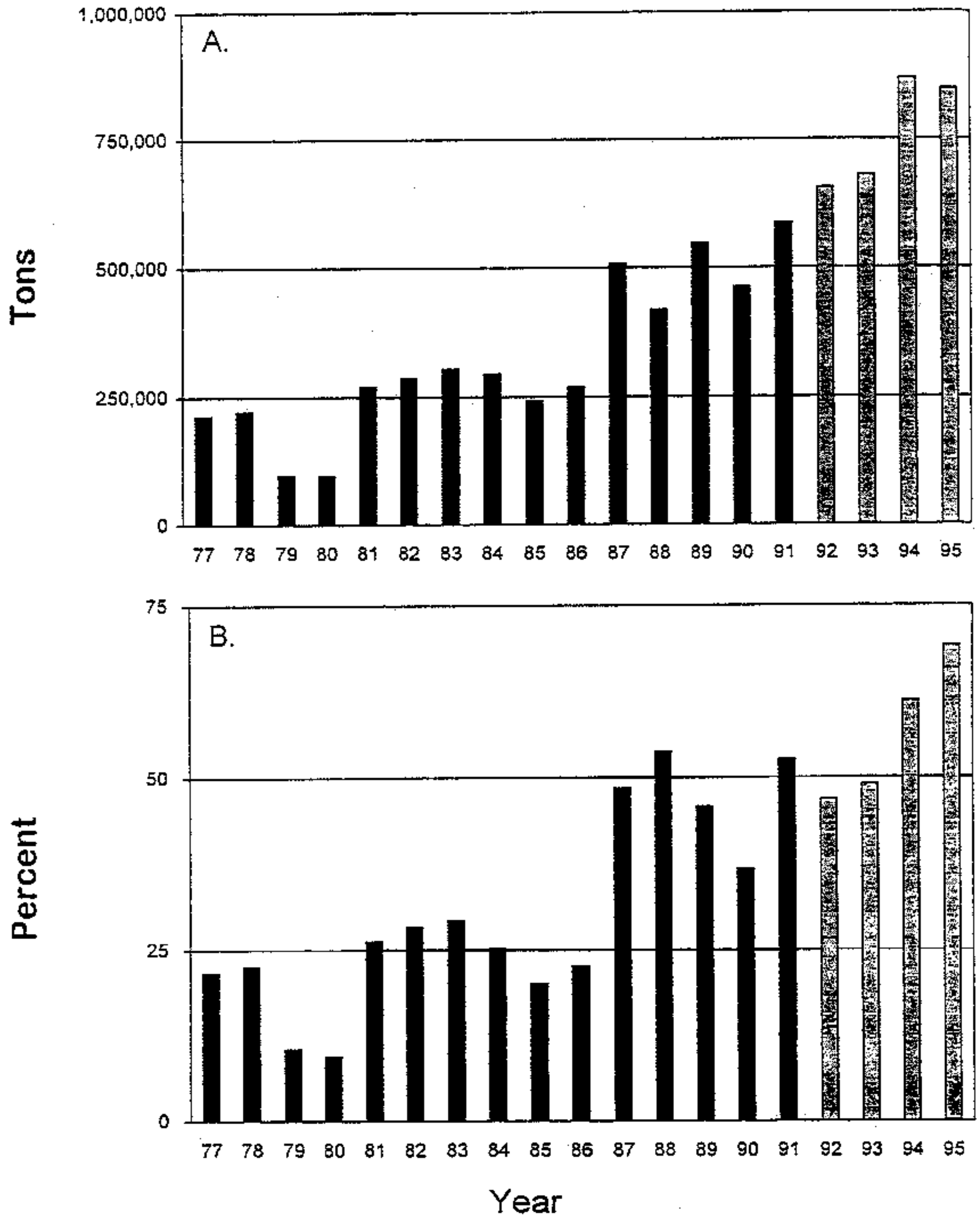
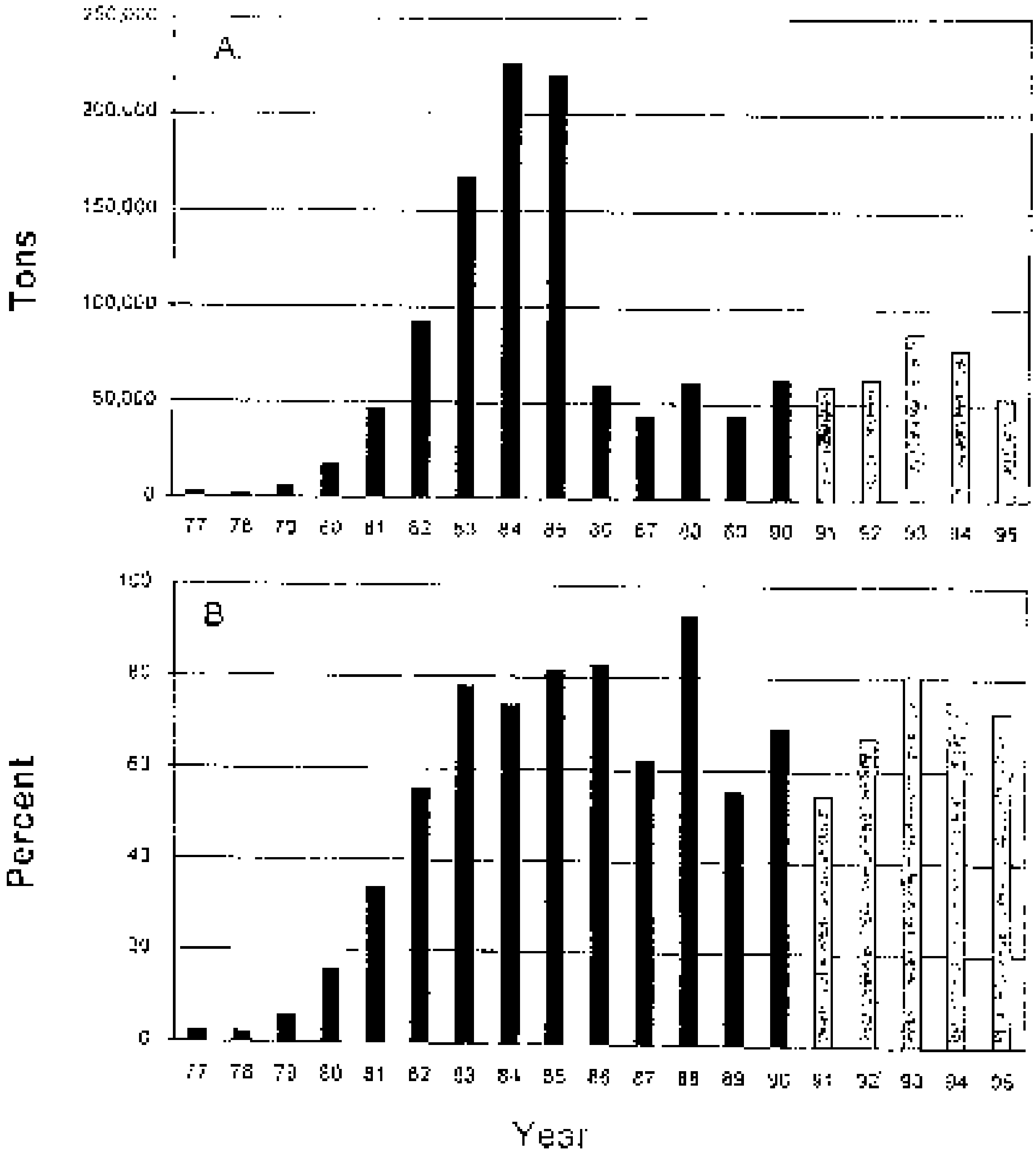


Figure 3. Pollock catch within Steller sea lion critical habitat in the Gulf of Alaska (GOA), 1977-1995. A. Tons of pollock caught within critical habitat. B. Percent of annual GOA pollock catch from critical habitat. Years when sea lion protective measures were in place are lightly shaded (1992-1995).



ENDANGERED SPECIES ACT CONSIDERATIONS

by Tamra Faris

Background The Endangered Species Act (ESA) of 1973 provides for the conservation of endangered and threatened species of fish, wildlife, and plants. The program is administered jointly by the Department of Commerce (NMFS) for most marine species, and the Department of Interior (FWS) for terrestrial and freshwater species.

The ESA procedure for identifying or listing imperiled species involves a two-tiered process, classifying species as either threatened or endangered, based on the biological health of a species. Threatened species are those likely to become endangered in the foreseeable future [16 U.S.C. §1532(20)]. Endangered species are those in danger of becoming extinct throughout all or a significant portion of their range [16 U.S.C. §1532(20)]. The Secretary, acting through NMFS, is authorized to list marine mammal and fish species. The Secretary of Interior, acting through the FWS, is authorized to list all other organisms.

In addition to listing species under the ESA, the critical habitat of a newly listed species must be designated concurrent with its listing to the "maximum extent prudent and determinable" [16 U.S.C. §1533(b)(1)(A)]. The ESA defines critical habitat as those specific areas that are essential to the conservation of a listed species and that may be in need of special consideration. The primary benefit of critical habitat designation is that it informs Federal agencies that listed species are dependent upon these areas for their continued existence, and that consultation with NMFS on any Federal action that may affect these areas is required. Some species, primarily the cetaceans, listed in 1969 under the Endangered Species Conservation Act and carried forward as endangered under the ESA, have not received critical habitat designations.

Listed Species The following species are currently listed as endangered under the ESA and occur in the GOA and/or BSAI groundfish management areas:

Northern Right Whale	*Balaena glacialis*
Bowhead Whale[2]	*Balaena mysticetus*
Sei Whale	*Balaenoptera borealis*
Blue Whale	*Balaenoptera musculus*
Fin Whale	*Balaenoptera physalus*
Humpback Whale	*Megaptera novaeangliae*
Sperm Whale	*Physeter macrocephalus*
Snake River Sockeye Salmon	*Oncorhynchus nerka*
Short-tailed Albatross	*Diomedia albatrus*
Steller Sea Lion[3]	*Eumetopias jubatus*

The following species are currently listed as threatened and occur in the BSAI and GOA management areas:

Snake River Fall Chinook Salmon	*Oncorhynchus tshawytscha*
Snake River Spring/Summer Chinook Salmon	*Oncorhynchus tshawytscha*
Steller Sea Lion[4]	*Eumetopias jubatus*
Spectacled Eider	*Somateria fishcheri*

[2]species is present in Bering Sea area only.

[3]listed as endangered in waters west of Cape Suckling.

[4]listed as threatened in waters east of Cape Suckling.

Section 7 Consultations. Because both groundfish fisheries are federally regulated activities, any negative affects of the fisheries on listed species or critical habitat and any takings[5] that may occur are subject to ESA section 7 consultation. NMFS initiates the consultation and the resulting biological opinions are issued to NMFS. The Council may be invited to participate in the compilation, review, and analysis of data used in the consultations. The determination of whether the action "is likely to jeopardize the continued existence of" endangered or threatened species or to result in the destruction or modification of critical habitat, however, is the responsibility of the appropriate agency (NMFS or FWS). If the action is determined to result in jeopardy, the opinion includes reasonable and prudent measures that are necessary to alter the action so that jeopardy is avoided. If an incidental take of a listed species is expected to occur under normal promulgation of the action, an incidental take statement is appended to the biological opinion. Section 7 consultations have been done for all the above listed species, some individually and some as groups. Below are summaries of the consultations.

Endangered Cetaceans. NMFS concluded a formal section 7 consultation on the effects of the BSAI and GOA groundfish fisheries on endangered cetaceans within the BSAI and GOA on December 14, 1979, and April 19, 1991, respectively. These opinions concluded that the fisheries are unlikely to jeopardize the continued existence or recovery of endangered whales. Consideration of the bowhead whale as one of the listed species present within the area of the Bering Sea fishery was not recognized in the 1979 opinion, however, its range and status are not known to have changed. No new information exists that would cause NMFS to alter the conclusion of the 1979 or 1991 opinions. NMFS has no plan to reopen Section 7 consultations on the listed cetaceans during the 1998 Total Allowable Catch specification process. Of note, however, are observations of Northern Right Whales during Bering Sea stock assessment cruises in the summer of 1997 (NMFS per. com). Prior to these sightings, and one observation of a group of two whales in 1996, confirmed sightings had not occurred.

Steller sea lion. The Steller sea lion range extends from California and associated waters to Alaska, including the Gulf of Alaska and Aleutian Islands, and into the Bering Sea and North Pacific and into Russian waters and territory. In 1997, based on biological information collected since the species was listed as threatened in 1990 (60 FR 51968), NMFS reclassified Steller sea lions as two distinct population segments under the ESA (62 FR 24345). The Steller sea lion population segment west of 144°W. longitude (a line near Cape Suckling, Alaska) is listed as endangered; the remainder of the U.S. Steller sea lion population maintains the threatened listing.

NMFS designated critical habitat in 1993 (58 FR 45278) for the Steller sea lion based on the Recovery Team's determination of habitat sites essential to reproduction, rest, refuge, and feeding. Listed critical habitats in Alaska include all rookeries, major haul-outs, and specific aquatic foraging habitats of the BSAI and GOA. The designation does not place any additional restrictions on human activities within designated areas. No changes in critical habitat designation were made as result of the 1997 relisting.

Beginning in 1990 when Steller sea lions were first listed under the ESA, NMFS determined that both groundfish fisheries may adversely affect Steller sea lions, and therefore conducted Section 7 consultation on the overall fisheries (NMFS 1991), and subsequent changes in the fisheries (NMFS 1992). The most recent biological opinion on the BSAI and GOA fisheries effects on Steller sea lions was issued by NMFS January 26, 1996. It concluded that these fisheries and harvest levels are unlikely to jeopardize the continued existence and recovery of the Steller sea lion or adversely modify critical habitat. NMFS has no plan to reopen Section 7 consultations on Steller sea lions during the 1998 Total Allowable Catch specification process, however, NMFS may consider amending the 1996 consultation.

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[5] the term "take" under the ESA means "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or attempt to engage in any such conduct" (16 U.S.C. §1538(a)(1)(B).

Pacific Salmon. No species of Pacific salmon originating from freshwater habitat in Alaska are listed under the ESA. These listed species originate in freshwater habitat in the headwaters of the Columbia (Snake) River. During ocean migration to the Pacific marine waters a small (undetermined) portion of the stock go into the Gulf of Alaska as far east as the Aleutian Islands. In that habitat they are mixed with hundreds to thousands of other stocks originating from the Columbia River, British Columbia, Alaska, and Asia. The listed fish are not visually distinguishable from the other, unlisted, stocks. Mortal take of them in the chinook salmon bycatch portion of the fisheries is assumed based on sketchy abundance, timing, and migration pattern information.

NMFS designated critical habitat in 1992 (57 FR 57051) for the for the Snake River sockeye, Snake River spring/summer chinook, and Snake River fall chinook salmon. The designations did not include any marine waters, therefore, does not include any of the habitat where the groundfish fisheries are promulgated.

NMFS has issued two biological opinions and no-jeopardy determinations for listed Pacific salmon in the Alaska groundfish fisheries (NMFS 1994, NMFS 1995). Conservation measures were recommended to reduce salmon bycatch and improve the level of information about the salmon bycatch. The no jeopardy determination was based on the assumption that if total salmon bycatch is controlled, the impacts to listed salmon are also controlled. The incidental take statement appended to the second biological opinion allowed for take of one Snake River fall chinook and zero take of either Snake River spring/summer chinook or Snake River sockeye, per year. As explained above, it is not technically possible to know if any have been taken. Compliance with the biological opinion is stated in terms of limiting salmon bycatch per year to under 55,000 and 40,000 for chinook salmon, and 200 and 100 sockeye salmon in the BSAI and GOA fisheries, respectively.

Short-tailed albatross The entire world population in 1995 was estimated as 800 birds; 350 adults breed on two small islands near Japan (H. Hasegawa, per. com.). The population is growing but is still critically endangered because of its small size and restricted breeding range. Past observations indicate that older short-tailed albatrosses are present in Alaska primarily during the summer and fall months along the shelf break from the Alaska Peninsula to the Gulf of Alaska, although 1- and 2-year old juveniles may be present at other times of the year (FWS 1993). Consequently, these albatrosses generally would be exposed to fishery interactions most often during the summer and fall--during the latter part of the second and the whole of the third fishing quarters.

Short-tailed albatrosses reported caught in the longline fishery include two in 1995, one in October 1996, and none so far in 1997. Both 1995 birds were caught in the vicinity of Unimak Pass and were taken outside the observers' statistical samples. The 1996 bird was taken near the Pribilof Islands in an observers sample.

NMFS has initiated three formal consultations with the USFWS since 1989 on the effects of the groundfish fisheries on short-tailed albatross. The biological opinions concluded that the fishery would not jeopardize the continued existence of the species (USFWS 1989, 1995, 1997). The incidental take limit is four birds in two years (USFWS 1997). NMFS does not intend to re-initiate consultation for the 1998 Total Allowable Catch specification process.

Spectacled Eider These sea ducks feed on benthic mollusks and crustaceans taken in shallow marine waters or on pelagic crustaceans. The marine range for spectacled eider has been elucidated since 1994 as the northern Bering Sea and Chukchi Sea. During the winter (November - April), the species is concentrated at sea approximately halfway between St. Lawrence and St. Matthew Islands. During the summer, Spectacled Eiders breed on the tundra.

NMFS initiated formal consultation with the USFWS on the potential effects of the crab fishery on Spectacled Eiders. The biological opinion concluded that only the C. opilio crab fishery potentially could interact with the species (primarily through collisions of birds with the superstructure of vessels), but that the fishery would not jeopardize the continued existence of the species. The incidental take limit is 10 birds per year. Observers in the opilio fishery have reported no take of spectacled eiders in 1995 through 1997. An expansion of the opilio crab fishery to spring CDQ fishing is planned for 1998, but NMFS has not yet re-initiated consultation with USFWS over possible effects of this change of the fishery on spectacled eiders.

Conditions for Reinitiation of Consultation. For all ESA listed species, consultation must be reinitiated if: the amount or extent of taking specified in the Incidental Take Statement is exceeded, new information reveals effects of the action that may affect listed species in a way not previously considered, the action is subsequently modified in a manner that causes an effect to listed species that was not considered in the biological opinion, or a new species is listed or critical habitat is designated that may be affected by the action.

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OCEANOGRAPHIC EFFECTS ON NORTH PACIFIC GROUNDFISH

by Jane DiCosimo

As described by Hare (1996), the climate of the North Pacific is driven by the location and intensity of seasonally varying atmospheric pressure cells. During the most climatologically active months of November to March, the Aleutian Low pressure system covers much of the North Pacific, while the Subtropical High pressure system is most active in the summer months. Each of these systems can cover an area of several million square kilometers. In addition to creating conditions that establish seasonal weather patterns, these atmospheric systems affect oceanic conditions via changes in vertical and horizontal flow driven by surface wind stress. Examples of wind-driven flow changes include redirection of surface currents, mixed layer depth turnover, and enhanced or suppressed coastal upwelling. These processes in turn affect biological primary production and, ultimately, upper-level trophic species.

El Niño is an abnormal state of the ocean-atmosphere system in the tropical Pacific Ocean (Bailey et al. 1995). It is a highly complex interaction, whereby warming of ocean waters transfers heat to the atmosphere. Higher ocean temperatures increase evaporation, increases rainfall, and changes atmospheric pressure, disrupting wind patterns and, thereby, affecting ocean currents. El Niño affects fisheries when the normal east-west trade winds die, or reverse, allowing the warm equatorial current to spread toward South America and the west coast of the U.S. This wedge of warm water, sometimes 400 ft deep, blocks the nutrient-rich cold water from rising to the surface. These changes trigger major fish movements and could disrupt fisheries for months or years. Scientists have warned of a coming El Niño event expected to occur in December 1997/January 1998, when ocean temperatures will be highest in the eastern Pacific. This El Niño may be larger than the 1982-83 event, the strongest on record. It is unknown how fisheries in the BSAI and GOA will be affected. Recruitment related to the 1993 ENSO should be evident in 1996/97 (Bailey et al. 1995).

Over the past century, the amplitude of this climate pattern has varied irregularly at interannual-to-interdecadal time scales (Mantua et al. 1996). There is evidence of reversals in the prevailing polarity of the oscillation occurring around 1925, 1947, and 1977; the last two reversals correspond with dramatic shifts in salmon production regimes in the North Pacific Ocean. This climate pattern also affects coastal sea and continental surface air temperatures, as well as streamflow in major west coast river systems, from Alaska to California. Widespread ecological changes related to interdecadal climate variations in the Pacific have also been noted. Dramatic shifts in an array of marine and terrestrial ecological variables in western North America coincided with the changes in the state of the physical environment in the late 1970's. Rapid changes in the production levels of major Alaskan commercial fish stocks have been connected to interdecadal climate variability in the northeast Pacific (Beamish and Boullion 1993, Hollowed and Wooster 1994), and similar climate-salmon production relationships have been observed for some salmon populations in Washington, Oregon, and California (Francis and Sibley 1991, Anderson 1996). Since at least the 1920's interdecadal fluctuations in the dominant pattern of North Pacific sea level pressure (SLP) have closely paralleled those in the leading North Pacific sea surface temperature (SST) pattern. It is this coherent, interdecadal time scale ocean-atmosphere co-variability that is the essence of the climate signature of the Pacific Decadal Oscillation (Mantua et al. 1996).

These El Niño-Southern Oscillation (ENSO) events along the west coast of North America are associated with the poleward propagation of oceanic long waves along the coast or shelf break resulting in deeper thermoclines, increased sea level, stronger poleward flow, and consequent redistribution of water properties with higher salinity and temperature (Simpson 1992). Atmospheric teleconnections that affect the north GOA include the intensification of the Aleutian low-pressure system, changes in the wind field, increased storminess in the GOA, and relaxed coastal upwelling. Wooster and Hollowed (1991) identified winter conditions alternating between warm and cool eras, each lasting between 6-12 years, with an average of 9.3

years. SSTs in the eastern North Pacific Ocean experienced an average period of 17 years (Wooster and Hollowed 1995). Decadal variations in the eastern Bering Sea are similar to, but not identical with, those inshore farther south (Bailey et al. 1995).

Recent evidence has suggested that the climate of the North Pacific, and in particular the activity of the Aleutian Low pressure system, has changed markedly from 20 years ago. Since the winter of 1976/77, winters in the North Pacific have generally been marked by intense, large-scale Aleutian Low events. The center of the low has deepened and shifted eastward by several hundred kilometers. The physical impacts of this change in behavior include: warmer air and sea surface temperatures in Alaska and Alaskan waters, more frequent and severe storm activity, increased vertical advection (upwelling), and decreased mixed layer depth across most of the Gulf of Alaska (Hare 1996).

Most (14/22) El Niño events since 1900 have been characterized by warmer than normal winter and spring seasons in the Pacific Northwest (Mantua 1997). The effect of ENSO on rainfall is much less dependable. Some events have brought more rainfall than normal (4/22), others less. The very strong 1982-83 event, which might be regarded as an analogue of this years event, was marked by heavier than normal rainfall. The typical El Niño signal in the Pacific Northwest is best expressed as a high probability for anomalously warm November-June air temperatures.

El Niño events are often associated with higher than average coastal sea levels. The 1982-83 event saw sea levels 20 to 30 cm above average during the winter months when storm activity was greatest over the Northeast Pacific. The combined effects of this short term sea level rise, severe storms, and swells from storms in the open waters of the North Pacific, lead to severe coastal erosion and damage to shorelines and property on PNW coasts. Long term impacts from such storms can result in ongoing erosion problems for many years in some instances. If summer drought is intense, then there is a significant decrease in nearshore coastal water quality and wetlands productivity. A relationship has been noted between El Niño years and increases in the occurrence of toxic algal blooms, although the exact causal mechanism is unknown. The El Niño event of 1982-83 was the strongest event in the historical record, at least since 1870. Because the emerging 1997-98 El Niño appears to be at least as intense as the 1982-83 event, the question whether 1982-83 can be used as an analogue for predicting how 1997-98 will unfold has been raised (Mantua 1997).

The 1991-93 ENSO event first appeared in the northern GOA in fall 1991 with warm sea surface temperatures (Bailey et al.1995). Pulses of increased sea level and anomalous circulation continued through summer 1993. The effects of this ENSO event on major groundfish species and Pacific herring in the northern GOA were examined by Bailey et al. (1995) and compared with the effects of previous ENSO events. Little evidence was found that the 1991-93 or 1982-83 ENSO affected landings of walleye pollock, Pacific cod, Pacific halibut, or arrowtooth flounder. Some changes in groundfish distribution were observed in 1993, but the effect was similar to changes observed in non-ENSO warm years. In general, warm ocean conditions have a positive effect on recruitment of northern stocks, but ENSO events appear to have an inconsistent effect on year-class strength within species and among species.

In a model of the circulation of the North Pacific, the major circulatory feature is the presence of two permanent oceanic gyres - the cyclonic Subarctic (also called the Alaska) gyre and the Subtropical gyre. These two gyres are fed by the eastward flowing Subarctic Current via its two coastal extensions, the northward flowing Alaska Current and the southward flowing California Current. The key aspect of the model is the “out of phase,” or inverse, relationship between the two gyres. In one state (Hollowed and Wooster's (1992) Type “B”), the Aleutian Low is intensified resulting in a spinup of the Subarctic Gyre and enhanced flow into the Alaska Current (Figure 1). Type B conditions have a well-developed Pacific high-pressure cell and an intense Aleutian low-pressure system resulting in strong circulation in the Gulf of Alaska accompanied by relatively high sea surface temperatures, sea level and deep thermoclines farther south. In the other state ("Type A"), featuring a weakened Aleutian Low, the California Current is strengthened at the expense of a weakened Alaska Current. Warm eras and isolated (some) El Niño events are associated with Type B circulation, cool eras, with Type A circulation. In the "regime shift" aspect of this general model, the circulation of the north Pacific changed from Type A to a Type B pattern in the winter of 1976/77 and has essentially remained locked in a Type B pattern since.

Upon examining a time series of recruitment indices for 15 groundfish stocks, Hollowed and Wooster (1992) identified a link between synchronous strong year classes in 1961, 1970, 1977, and 1984 and oceanic conditions (Type B circulation). Three years (1970, 1977, and 1984) were associated with El Niño events. They suggested that oceanic conditions influence marine fish by altering advection, turbulence, or physiological processes, which may influence fish behavior, starvation, predation, and infestation. Quinn and Niebauer (1995) found a significant correlation between high pollock recruitment at age 2 with above average air temperature and bottom temperature and reduced ice cover, lagged by one year.

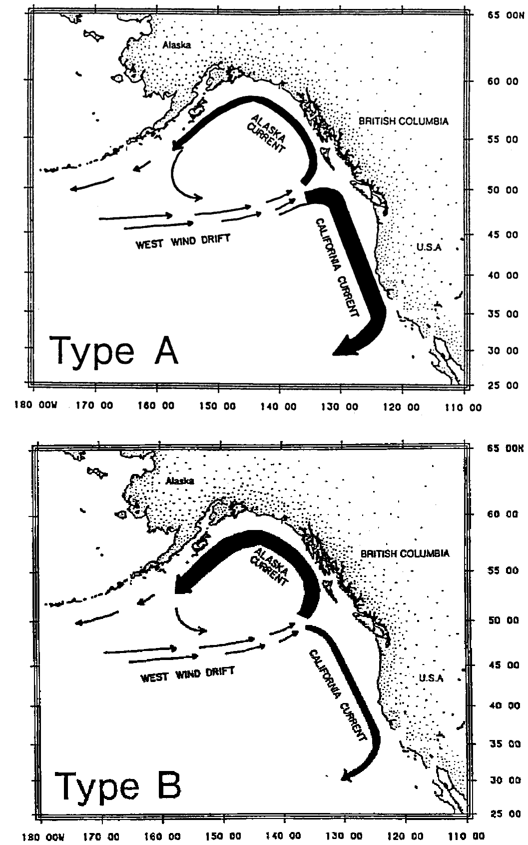

Figure 1. Circulation patterns associated with Type-A and Type-B ocean conditions.

Influences of ocean climate on plankton and fish production have been reported by Robinson (1994) and Shugimoto and Tadokoro (1997). Gargett (1997) has been suggested that water column stability may be one mechanism by which the physical environment influences phytoplankton production. Ingraham et al. (in press) linked sea surface drift and tree rings to a decadal shift of northeast Pacific Ocean water movement.

As summarized in Hare (1996), several investigators have speculated that the 1976/77 regime shift is but the most recent in a succession of events. In the 20th century, four distinct climatic regimes have occurred (Figure 2). The regimes have averaged 25-30 years in duration, with the transitions taking place in the mid-1920s, mid-1940s and mid-1970s. The relationship of these regimes to the ENSO phenomenon is unclear but has important ramifications for biological research on marine resources.

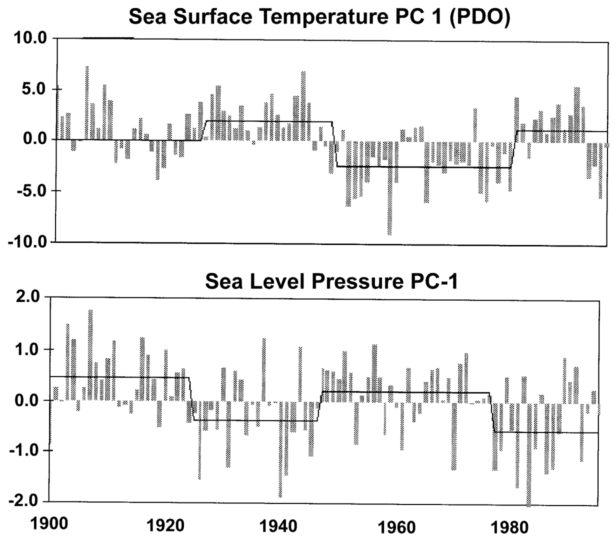

Figure 2. Two indicators of large-scale, long-term climate variability over the North Pacific in the 20th century. The time series show the polarity of the Pacific Decadal Oscillation as reflected in winter SST and SLP, along with intervention model fits (Reproduction from Mantua et al. in review.)

Biological changes associated (or at least co-incident) with these climatic regime shifts are evident throughout the North Pacific and Bering Sea

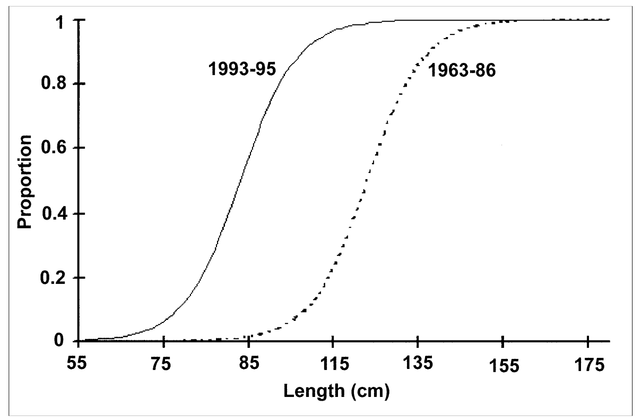

Figure 3. Proportion mature at length of Alaska female halibut during two distinct regimes.

(Hare 1996). Since the 1976/77 regime shift, sharp increases have been noted in primary (Venrick et al. 1987) and secondary (zooplankton) (McFarlane and Beamish 1992, Brodeur and Ware 1992, Brodeur et al. 1996) production, as well as in salmon (Hare and Francis 1995) and many groundfish species (Beamish 1993). Coastal pelagics experience temperature-driven dislocations in distribution (both horizontally and vertically) and these dislocations affect sea birds, particularly gulls and murres (Mantua 1997). Demersal species are not much affected by changes in surface temperature during an El Niño event; nor are dungeness crab populations but we do not have detailed knowledge of bottom temperature variations associated with El Niño (Mantua 1997). Many of the flatfish species appear to maintain their distributions independent of temperature variation. Roundfish species like pollock and Pacific cod may vary their distribution in response to temperature (Perry et al. 1994). Herring and other stocks of small pelagic fishes may be more affected by ENSO events. In particular, decreased catches, recruitment, and weight-at-age of herring are sometimes associated with ENSO events. A dramatic decline in average size of Pacific halibut across much of its range also began following the winter of 1976/77 (Figure 3) (Clark 1995).

Concurrently, other populations including king crab (Blau 1986), shrimp (Anderson 1991), Steller sea lions (Springer 1992) and several species of marine birds (Piatt and Anderson, in press), declined sharply with the onset of the new regime. A variety of seabirds which feed mostly on pelagic forage fishes or the pelagic juvenile stages of groundfish suffered widespread mortalities and breeding failures in the GOA during ENSO years of 1983 and 1993. The effects on seabirds were also observed over a wide geographic range, from California to the western Bering Sea. Seabirds may be more sensitive (or at least their response is more visible) to ENSO events (Bailey et al. 1995). Large scale seabird mortalities occur periodically in Alaskan waters, with the largest of these occurring during ENSO years. Decreased seabird feeding levels, high mortalities, and reproductive failures observed in the GOA in 1983 and 1993 may reflect changes in the abundance or distribution of small pelagic fish prey (Bailey et al. 1995). Pollock and sand lance replaced capelin as the dominant prey in the diets of five GOA seabird species, reflecting the crash in capelin populations and dramatic increase in pollock stocks in the late 1970s. Seabirds and climatological events are discussed elsewhere in this document.

Miles (1997) discussed policy implications for managing fish stocks experiencing multi-dimensional effects from global climate variability. Details of the effects expected as a result of human-induced global climate change are still poorly understood and there is still substantial uncertainty embedded in the predictions generated by general circulation models (GCMs). Since the resolution of the GCMs is poor, our understanding of the regional-scale effects of global climate change (GCC) is rudimentary. Miles suggested that it would not be advisable simply to parameterize the GCMs downwards to regional scales because such an approach could yield spectacular errors. In the PNW, the dominant climate signal, i.e., ENSO, would be linked to regional climate variability impacts; and secondly regional climate impacts would be linked to response strategies. The level of uncertainty attached to predictions of specific impacts should be estimated.

As stated by Dowlatabadi and Morgan (1993): Whereas the arguments for integrated assessment are intellectually compelling, current understanding of the natural and social sciences of the climate problem is so incomplete that today it is not possible to build traditional analytical models that incorporate all the elements, processes, and feedbacks that are likely to be important....The result has often been that the policy discussion has focused on what we know, rather than what is important....it will be necessary to evolve a new class of policy models that allows an integration of subjective expert judgment about poorly understood parts of the problem with formal analytical treatments of the well-understood parts of the problem.

<u>Sitka Gyre</u> (The following is adapted from Melsom et al. (1997)) The Sitka gyre is a frequently observed anticyclonic feature in the Gulf of Alaska near 57°N. One or more anticyclonic eddies exist off Sitka during most years, notably in 1958, 1960, 1961 and 1977. Some evidence indicates the Sitka eddy may have ocurred in 1954, 1956, 1959, 1962 and 1967.

Simulations of a coastal current, corresponding to the Alaska Current, by Melsom et al. (1997) indicate the current is strongest during winter, when the flow is northward. In spring the current weakens, moves slightly offshore, and breaks into eddies. During summer its direction is frequently southward. A similar seasonal cycle is found in observational data, where it is attributed to a shift in the atmospheric circulation from a surface pressure low in winter to a summer high. The transport and the vertical velocity shear associated with the coastal current reach maximum values in December or January. At this time, the current starts to meander. The alongshore wavelength and offshore amplitude of the meanders are typically 200 km and 40 km, respectively. However, the amplitude may become ~100 km, after which the current usually breaks into eddies. The meandering is observed in both of the layers under consideration. Generally, the horizontal pressure gradient is significantly larger in layer 1 than in layer 2. Hence, the motion in the meanders is strongly baroclinic and the accompanying vertical velocity shear is significant.

As the meanders break up, anticyclonic and cyclonic eddies are formed by baroclinic instability. The anticyclonic eddies are generally larger than the cyclonic eddies. The cyclonic eddies dissipate quite rapidly, whereas the anticyclonic eddies sometimes survive for well over a year. Typically, the stronger anticyclonic eddies are generated during winter. The eddies are seen to propagate slowly southwestward (i.e., offshore), with an estimated propagation speed of 0.5-1 cm/s, or ~200 km/year. However, the direction of propagation may temporarily be reversed, possibly due to the local wind forcing.

The wavelength of the most rapidly growing disturbance is a function of the buoyancy, layer thickness and latitude. In the coastal regions of the Gulf of Alaska this scale varies from ~50 km to ~75 km for upwelling and downwelling perturbations, respectively. Upwelling perturbations stabilize the flow and do not yield eddies. The diameter of the Sitka eddy is observed to be 200 km - 300 km, with a vertical isopycnal deflection of 20 m - 100 m. Furthermore, the initial location of the Sitka eddy is 150 km - 200 km off the coast of Baranof Island, and it can persist for 10 to 17 months, drifting southwestward.

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ANECDOTAL INFORMATION FROM THE FISHING FLEET, COASTAL COMMUNITIES AND VARIOUS AGENCIES: Incorporating these observations into the annual SAFE document Ecosystem Considerations chapter

by Ivan Vining, Chris Blackburn, Richard Merrick , Vivian Mendenhall, and John Sease

A committee was established at the November 1996 Plan Team meeting, to discuss the issue of incorporating local and traditional knowledge into the Ecosystem Considerations chapter of the SAFE documents. The new section would incorporate information (anecdotal or professional) from the fishing fleet, coastal communities and other agencies, specifically recording attributes of the environment (mostly marine) and/or fishery which had changed in that year (not including regulations). Furthermore, it would not act as a "historic perspective" document, since such a section could be overwhelming both in writing, and content. The basic framework was designed and modified into a useable document (see attached outline). It is recognized that the details for the framework could change from year to year, which is why we kept the categories as broad as possible.

The committees major concern was the implementation of a program for this section. Specific concerns were: data gathering, storing, using, and checking; Ecosystem Chapter section compiling and writing; and feedback to contributing sources. The committee also noted that, in general, any sizable database requires a specific person or group to set it up, enter data and maintain it. This is neither easy nor cheap. The following is the specific thoughts and recommendations to address the concerns:

Data Gathering. This aspect deals with both how the data would be collected and also who would be ultimately in-charge of it. To receive the information, a few ideas presented themselves. Forms could be developed and given to various agencies (ADF&G, NMFS, and Advisory Committees as some examples) to poll and receive information both from external and internal sources of the organizations. A web site could be developed and advertised to interested parties. Both of these sources would have data forms similar to the draft framework and include questions such as: What was observed? Who observed it? When and where did they observe it? What makes the observation unusual? The question of who would ultimately be in-charge of the data, was a more difficult question, since the amount of data being received in a year could be quite substantial. It was thought perhaps this might be managed by several plan team members, or several council staff.

Data Storing. Similar to "data gathering", there is the logistics of storing and the person(s) to store it, but also who enters the data. It was proposed that the information be kept in a relational database. If such databases were developed in several locations (with common software) it would be fairly straight forward for a person to combine for a summary each year for the SAFE documents.

Data Using. This was presented as who would have access to the data in raw form, other than the annual SAFE documents. Since, to a large extent, the data would be considered anecdotal there was concern that people would use it as "scientific." However it was also mentioned that the data should have a clear "mission".

Data Checking. This was considered a fairly large category. This would include checking for obvious errors, such as marine observations on land, wrong dates and wrong locations. Beyond the obvious errors, there would be questionable data, such as observations of VERY unlikely species (penguins off Kodiak), temperatures (-175 degrees C or F), behavior (pollock bow riding), etc. The most difficult will be those observations which there are few observations (maybe one), though plausible (i.e. a walrus in Chignik Lagoon, which happened in the summer of 1979) and what should be considered abnormal. Is a beached sei whale on Kodiak worth noting, probably, but maybe not a beached gray whale.

Compiling and writing. Each year, a person (or group) will need to compile that years information and send it to the Plan Teams in a timely manner. Therefore, a "year" of data will likely go from August to August, or June to June. Once again this could be a major undertaking, especially if there were a large amount of data.

Feedback to Contributing Sources. Though it is recognized that each year the information would be placed in the SAFE documents, it was felt by several committee members that SAFEs would not reach all contributing sources and there needed to be a method to provide for feedback to all contributors. One idea was a letter to all individuals who presented information, or putting out a "newsletter" to all contributors similar to (if not exactly) what was written in the SAFE documents.

Anecdotal Information from the Fishing Fleet, Coastal Communities, and Various Agencies

Gear Changes
- How and why was the gear changed?
- What effect did it have?
- How many people did it?

Groundfish Species Composition and Distribution
- Major difference in bycatch ratios.
- Unusual absence or presence of a species in an area.

Groundfish Behavior or Physical Conditions
- Location by depth.
- Migration patterns (moving more quickly, traveling deeper).
- Feeding on animals not normally considered prey or low importance prey species.
- Unusual feeding behavior.
- Unusual schooling behavior (not balling, or balling).
- Unusual physical characteristics (long and skinny, 3 eyes etc.).
- Parasite changes (more, less or new).

Oceanic and Atmospheric Conditions
- Major differences in seawater temperature, color or clarity.
- Current strength or direction.
- Major differences in wind patterns, air temperature, cloud cover, or storm occurrences.
- Pack ice location or thickness, or time arriving or breaking up.

Other Fisheries
- Salmon and herring changes in return size, timing or size/sex distributions.
- Shellfish changes in size/sex distributions, physical location or catches.
- Forage/bait fish changes in schooling, numbers locations or timing.

Marine Mammals and Birds
- Unusual changes in numbers (including absence and presence) or behavior.
- Unusual concentrations or die-offs.

Terrestrial Influences
- Land-mammal or birds absence or presence
- Land-mammal or birds concentrations or die-offs.
- Unusual vegetation or amounts
- Changes in seasonal elements (e.g. pollen and run-off).

Other Unusual or Unexpected Occurrences

Rare or exotic species
Oil spills or ship wrecks
Seismic activity (volcano eruption, earthquake)
Excessive or unusual debris (hundreds of toy animals)
Unusual vessel or aircraft traffic, timing or amount (War Games in Shelikof Straits)
Any Other Observations or Concerns About the Fishery or Marine Environment

Anecdotal Observations from 1997

- A massive bloom of coccolithophores occurred in the eastern Bering Sea, July through August 1997. The flagellated coccolithophores reflected light and turned the waters an aquamarine color. The bloom reduced light for other primary producers (diatoms and other phytoplankton) and may have alter trophic dynamics of the Bering Sea food web. More information is available from Tiffany Vance, or from her internet site (http://rho.pmel.noaa.gov/~vance/SEAWIFS/EOS.HTML).

- A number of unexpected changes in abundance of fish and other biota were observed. The returns of pink salmon in Alaska were much lower than expected for all regions of the state. Similarly, the sockeye salmon returns for Bristol Bay were well below forecast. Jellyfish in the Bering Sea were observed to be in high abundance.

- There were several observations of rare and exotic species in 1997. A right whale and her calf were observed in the Bering Sea by an observer. Off Kodiak Island, a Mola mola (ocean sunfish) was observed, and a pelagic armorhead and a jack were caught. Greenland turbot and a large shark (possible a white shark) were taken in setnets in the Shumagin Islands.

- Sea surface temperatures were well above normal in the summer of 1997. In the Bering Sea, temperatures reached 3-5°C above normal in July. In the central Gulf of Alaska, sea surface temperatures averaged 3°C above normal.

- Four stone spearheads were found in a bowhead whale taken for subsistence purposes off Barrow. Recovery of these spearheads indicate that whales may live longer than previously thought, as steel replaced stone spearheads around the turn of the century.

- As discussed earlier in this chapter, there was a large die-off of seabirds (primarily shearwaters) along the north and south sides of the Alaska Peninsula.